SEWAGE AND INDUSTRIAL WASTES

JOURNAL of the FEDERATION OF SEWAGE AND INDUSTRIAL WASTES ASSOCIATIONS

ANNUAL CONVENTION NUMBER

Special Features

Frothing in Treatment Plants—Polkowski et al.

Industrial Public Relations—Lloyd

Roughness Coefficients in Sewers—Schmidt

Impoundments and DO—Kittrell

Combined Treatment—Powell, Lamb, and Ritter

Operator's Corner

Sulfide Control, Wastewater Transformation

Program—Page 1111

Thirty-Second Annual Meeting—Oct. 12–15, 1959
Statler Hilton Hotel and Dallas Memorial Auditorium
Dallas, Texas

SEPTEMBER 1959—VOL. 31, No. 9

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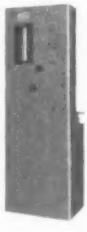

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SEWAGE AND INDUSTRIAL WASTES

Journal of the Federation of Sewage and Industrial Wastes Associations

Volume 31 **September 1959** **Number 9**

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"Controlled Digestion" Additions at Oakland

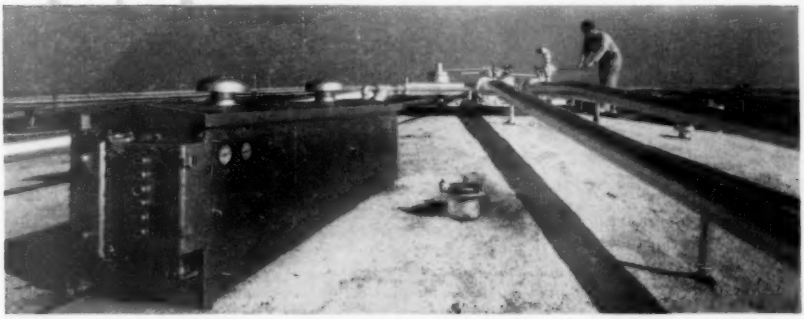
California's East Bay Municipal Utility District has made commendable steps in their clean-up program to curb pollution of the San Francisco Bay.

Their sewage treatment plant was completed in 1951 and included the following P.F.T. equipment: three 95' Floating Covers, three #1500 Heaters and Heat Exchangers, three Floating Cover Position Indicators, Gas Safety Equipment.

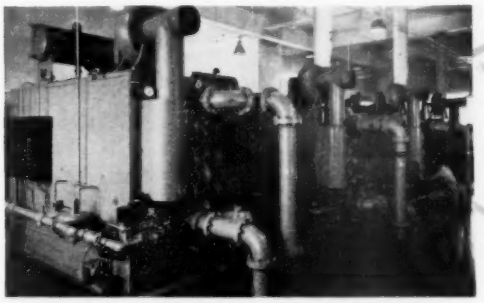
Continuing their program, in 1958 P.F.T. equipment was *again* selected which included: one 95' Floating Cover, another #1500 Heater and Heat Exchanger and a Floating Cover Position Indicator.

1958's additions embodied all the latest digestion controls including P.F.T. Pearth Gas Recirculation for increased effectiveness of the new unit.

Plant designed by—Engineering Department—East Bay Municipal Utility District.



Above—P.F.T.'s Pearth Gas Recirculation equipment on newly added 95' P.F.T. Floating Cover Digester.



Above—Additional P.F.T. Heater and Heat Exchanger installed in 1958. Notice the perfect blending with those installed in 1951.

P.F.T.

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A monthly Journal devoted to the advancement of fundamental and practical knowledge concerning the nature, collection, treatment and disposal of sewage and industrial wastes, and the design, construction, operation and management of such works. The Journal was known as *Sewage Works Journal* until January 1950.

EDITORIAL AND EXECUTIVE OFFICES: 4435 Wisconsin Ave., N.W., Washington 16, D. C. Send all manuscripts, advertising copy, subscriptions, address changes, etc., to this address.

PUBLICATION OFFICE: Prince and Lemon Sts., Lancaster, Pa.

SUBSCRIPTION RATES: Members of local associations affiliated with the Federation, $5.00 per year ($7.50 starting Jan. 1960). Non-members: U. S. and Canada, $7.50 per year ($10.00 starting Jan. 1960); other countries, $9.00 ($11.50 starting Jan. 1960). (Foreign subscriptions must be accompanied by International Money Order.) Single copies: United States, $1.00 each; Foreign, $1.25 each.

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REFERENCE SERVICE: Sewage and Industrial Wastes is indexed regularly by *Industrial Arts Index* and *Engineering Index*. Microfilm copies of this Journal may be procured from University Microfilms, Ann Arbor, Mich. This service is limited to regular subscribers only.

Library of Congress Catalogue Card Number: 42-19992.

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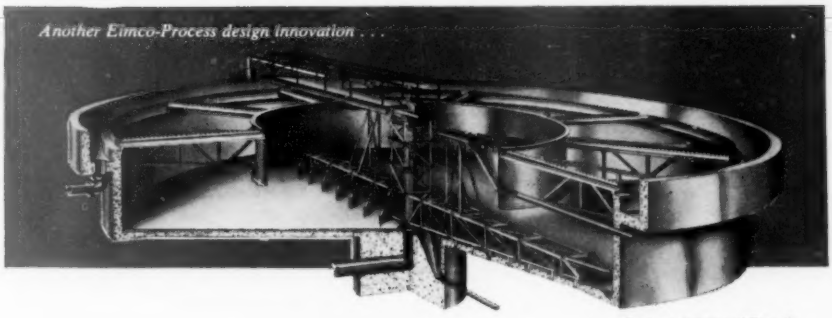

Cutaway drawing of Type C Flotator-Clarifier, a center column supported unit suitable for tanks to 100 ft. diameter. Beam supported mechanisms are available for smaller tanks.

EIMCO-PROCESS FLOTATOR-CLARIFIER PROVIDES EXCELLENT REMOVALS ON WIDELY VARYING FLOWS

Specifically designed to handle waste flow surges yet operate efficiently during periods of low flow, the Flotator-Clarifier represents a new concept in clarification. Through a combination of dissolved air flotation and conventional sedimentation in a single tank, all types of solids—settleable, floating and those which tend to remain in suspension—are rapidly removed. Septicity and odor formation are minimized, and suspended solids, C.O.D. and B.O.D. removals equivalent to those of a conventional clarifier are obtained in about half the tank area.

The Flotator-Clarifier is available in a variety of types, sizes, modifications, and with complete or partial pressurization. It is ideally suited to primary clarification in sewage treatment; oil, grease and other suspended solids removal from trade wastes; and removal or recovery of finely divided solids and low specific gravity liquids from industrial process streams.

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Bulletin SM-1008 covers design features of the Flotator-Clarifier. Bulletin B-292 describes the Isleton installation, shown below, in more detail. Copies are yours on request.

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PROCESS ENGINEERS, INC. *division*
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B - 419

. . . another outstanding installation

Partial feed pressurization and recirculation are features of this 32 ft. dia. Flotator-Clarifier at the Isleton, California, primary sewage treatment plant. The unit provides proper treatment of seasonal peak loads of cannery wastes, yet operates during periods of low flow without creating septic or malodorous conditions. Solano Engineers Associated, Vallejo, Calif., were the consulting engineers responsible for the design of this plant.

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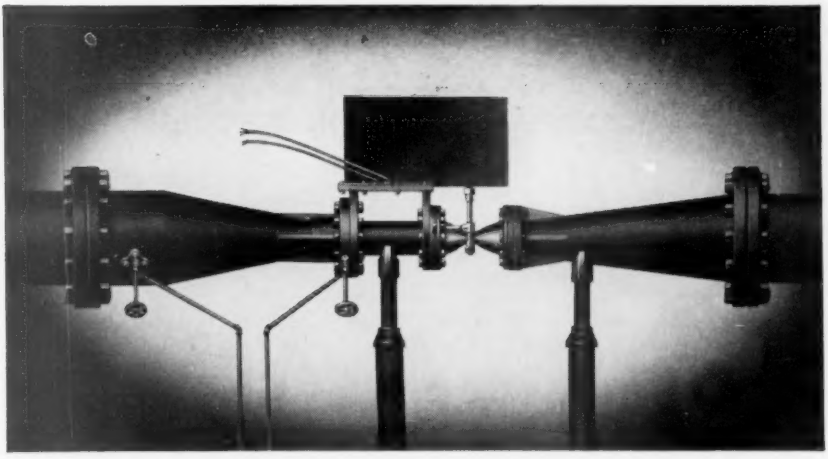

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Association	*Place*	*Time*
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North Dakota Water and Sewage Works Conf.	Dacotah Hotel Grand Forks, N. D.	Sept. 23–25, 1959
Missouri Water and Sewerage Conf.	President Hotel Kansas City, Mo.	Sept. 27–29, 1959
Canadian Institute on Sewage and Sanitation	Royal York Hotel Toronto, Ont.	Sept. 28–30, 1959
Puerto Rico Water and Sewage Works Assn.	Condado Beach Hotel, San Juan, P. R.	Oct. 2, 1959
New England Sewage and Industrial Wastes Assn.	Biltmore Hotel Providence, R. I.	Oct. 21–22, 1959
W. Va. Sewage and Industrial Wastes Assn.	Chancellor Hotel Parkersburg, W. Va.	Oct. 29–30, 1959
Pacific Northwest Sewage and Industrial Wastes Assn.	Hotel Tioga Coos Bay, Ore.	Oct. 29–31, 1959
Nebraska Sewage and Industrial Wastes Assn.	Sidney Motor Hotel Sidney, Nebr.	Nov. 5–6, 1959
North Carolina Sewage and Industrial Waste Assn.	Washington Duke Hotel Durham, N. C.	Nov. 9–11, 1959

THIRTY-SECOND ANNUAL MEETING

Federation of Sewage and Industrial Wastes Associations
Host—Sewage and Industrial Wastes Section,
Texas Water and Sewage Works Association
Statler Hilton Hotel, Dallas, Texas

Technical Meetings and Exhibits—Dallas Memorial Auditorium
October 12–15, 1959

The ideal sewage treatment plant for small communities, motels, industrial plants and institutions.

Another AERO-ACCELATOR® plant

installed for Summit Park Sanitorium

The Summit Park Sanitorium at Pomona, New York, has installed another "AERO-ACCELATOR" activated sludge plant to handle its increased need for sewage treatment. The selection was based on five years performance of the first unit with consistently good treatment, and low operating and maintenance costs.

This type of plant will provide 90-95% B.O.D. and suspended solids removal. As a *plus* value, it will afford substantial savings in space and in the cost of installation because of its compact design.

"AERO-ACCELATOR" plants, described in Bulletin 6510, can be custom-designed for all municipal and industrial requirements regardless of capacity. It will pay you to investigate.

SEE YOUR CONSULTING ENGINEER if you are planning *any* installation. His services are essential for the design of the plant and selection of equipment that will best meet your requirements.

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CAST IRON PIPE WINS THE VOTE

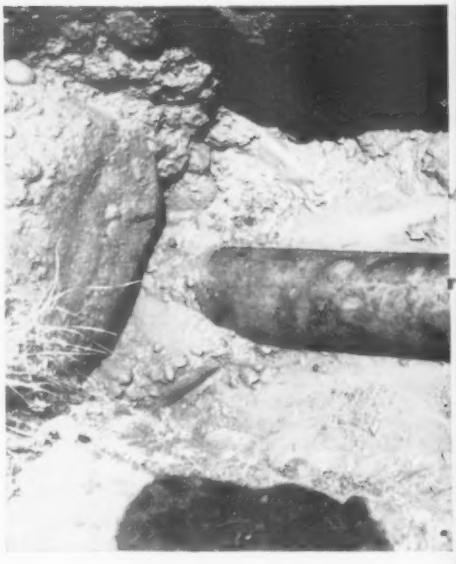
Recently a questionnaire was mailed to water utility managers all over the U.S. One question asked was: *What kind of pipe do you prefer and why?* With 42 states heard from, the vote is overwhelmingly in favor of cast iron! Here are typical comments:

"Cast iron pipe has been in use for 200 years, and the record speaks for itself. All the other types have their use, but we would not recommend them in a well-built, expanding water works distribution system or large transmission lines."

—Illinois

"1. Cast iron pipe is permanent—long life. 2. Lined pipe cuts down complaints of 'red' or 'rusty' water. 3. Mechanical joints are time and labor-saving over other types of joints, and are more flexible."

—Iowa



"Long life has been proven. I have personally observed pieces cut out of existing systems which were laid prior to the turn of the century. Such observations indicated the pipe to be as good as the day it was laid."

—Kansas

HANDS DOWN!

"We are located in a limestone area. We find cast iron pipe will absorb more rock damage than any other pipe. We also use cement lined pipe to overcome our corrosion condition which exists in our water."

—Pennsylvania

"It is very easy and fast to lay, and you can swing the joint enough in places where you can save time and money."

—New Jersey

THREE REASONS WHY CAST IRON PIPE IS AMERICA'S GREATEST WATER CARRIER:

1. More miles of underground cast iron water mains are now in use than of all other kinds of pipe combined.
2. More miles of cast iron water mains are now being purchased and laid than of any other kind of pipe.
3. Impartial surveys prove that today's water utility officials and consulting engineers prefer cast iron pipe for underground water distribution by an overwhelming majority.

...good reasons for you to choose

CAST IRON PIPE

THE MARK OF THE 100-YEAR PIPE

Specify IOWA for every job

Iowa's complete line of valves for treatment plants assures you of efficient operation, low maintenance cost, and replacement parts when needed in years to come.

IOWA CHECK VALVES—Swing gate type for use in either horizontal or vertical pipe lines. Bronze trimmed throughout. Stainless steel hinge pins. Leather or rubber faced gates, or solid bronze, as desired—aluminum gates available for air service.

IOWA MEDIUM AND LOW PRESSURE VALVES—either non-rising stem or outside screw and yoke types. Designed as carefully as those conforming to A.W.W.A. specifications but with lighter construction for lower pressures.

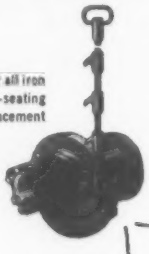
Write TODAY for descriptive literature

IOWA FLAP VALVES—all iron; can be furnished with bronze hinge bolts or fully bronze mounted—including bronze bolts, flap ring and seat ring—when required.

CLOW HYDROSTATIC RELIEF VALVES — commonly used in bottom of concrete tanks to prevent ground water from floating the tank. Close-grained cast iron body and lid; lead seat ring and lid ring. Cast iron grate in bottom prevents foreign matter from entering tank.

IOWA PLUG DRAIN VALVES—either rising or non-rising stem type. High strength cast iron bodies; bronze stem, operating nut, disc ring and seat ring; rustproof steel bolts and nuts. Handwheels, extension stems, plain or indicating floor stands if required.

IOWA SLUICE GATES—can be used in lines having both seating and unseating pressures. High strength cast iron, bronze mounted, with solid bronze adjustable wedges. Can be equipped with cylinder or motor unit for automatic operation.



IOWA SHEAR GATES—either all iron or iron, bronze mounted. Gate-seating wedges bolted on, permitting replacement without replacing frame.

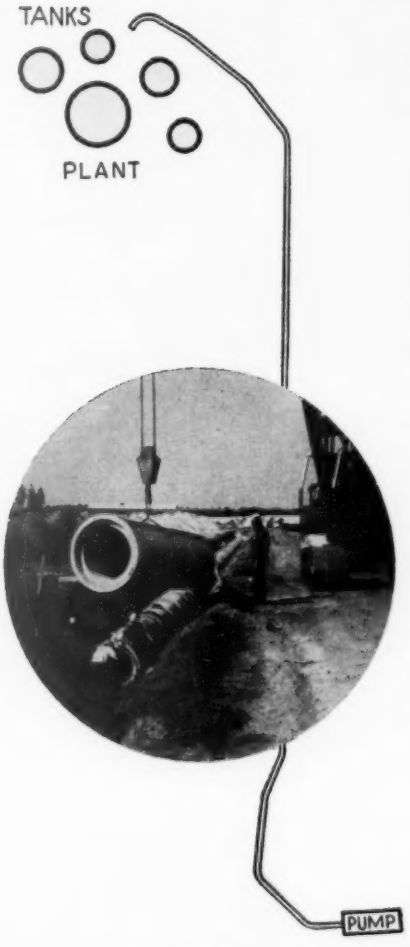
For 50 years a reliable source for precision engineered products

IOWA VALVE COMPANY

A Subsidiary of James B. Clow & Sons

Oskaloosa, Iowa

the problem...



Problem: Move 30,000 gallons of sea water per minute through aggressive soil and ground water.

The Project: Magnesium-oxide plant for Michigan Chemical Company at Port St. Joe, Fla.

The Engineer: Cunningham-Limp Company, Detroit, Mich.

The Solution: 36″ diameter Cen-Vi-Ro Water Pipe made with sulphate resisting Portland Cement and limestone aggregate; two inches of concrete cover for the reinforcing steel; six inches of loose oyster shell all around the pipe.

The Result: Service life estimated at more than 50 years.

Cen-Vi-Ro Pipe . . . engineered and made to your specifications . . . serves you better. When your job calls for concrete pipe, call Concrete Pipe Division, Vulcan Materials Company, Atlanta, Georgia.

CONCRETE PIPE DIVISION

VULCAN MATERIALS COMPANY

P.O. Box 6226, Station H, Atlanta, Georgia • JAckson 4-6244

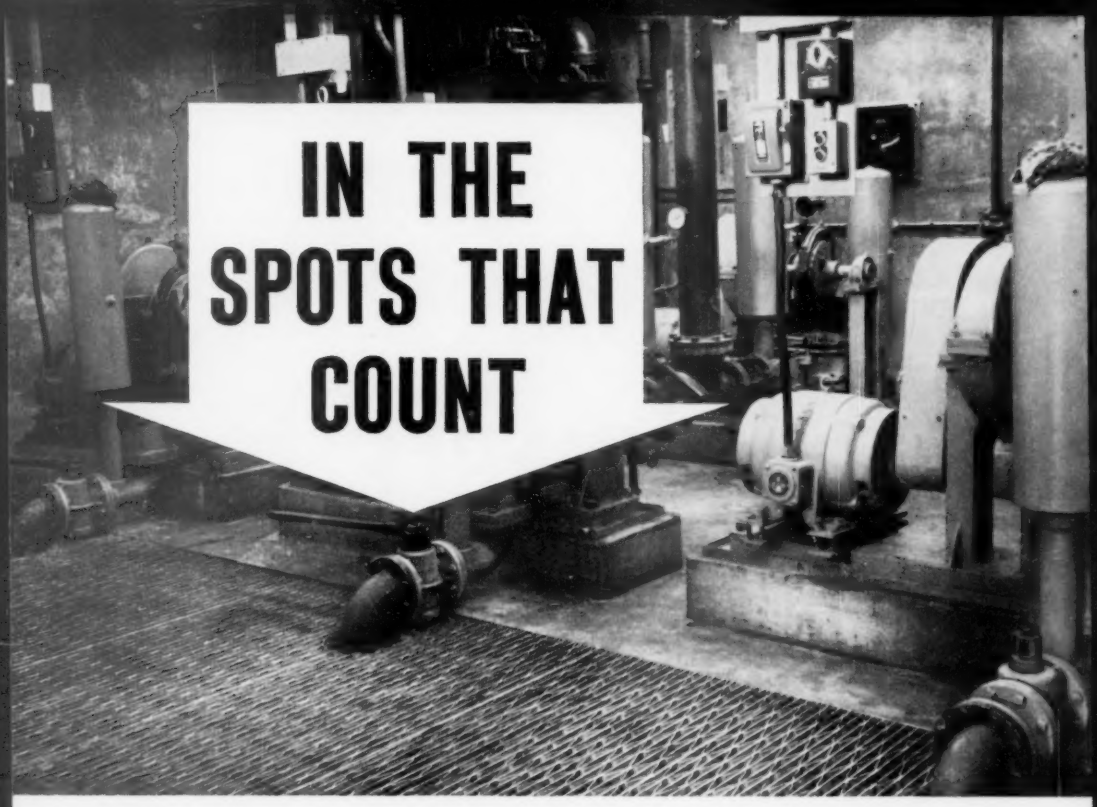
Owner:	City of College Station, Texas
Engineers:	Homer A. Hunter Associates Dallas, Texas
Design Flow:	0.52 MGD
Lakeside Equipment:	2 — 24′-0″ Spiragesters 1 — 120′-0″ Rotary Distributor 1 — 35′-0″ x 9′ SWD Spiraflo Clarifier

SPIRAGESTERS® are used singly for projects under 6000 P.E. They give superior results with the minimum of operating skill. Construction and operating costs are among the lowest. Plant expansion available by adding another Spiragester or easily converting the tank to a digester. Spiragesters are now installed throughout the U. S. Also Canada and foreign countries. As at College Station, Lakeside provides trickling filter and Spiraflo final clarifier equipment for a complete treatment plant. *Write for Bulletin 100.*

LAKESIDE

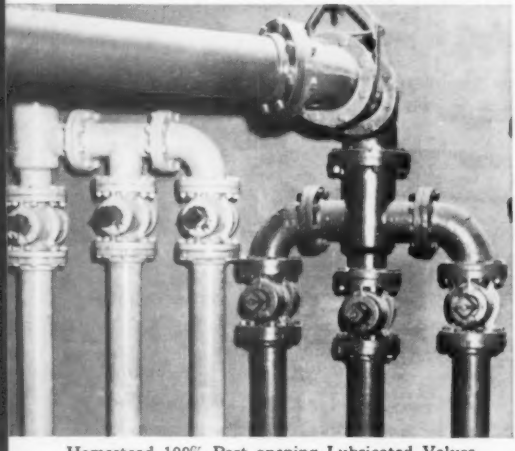
ENGINEERING CORPORATION

222 West Adams St., Chicago 6, Illinois



IN THE SPOTS THAT COUNT

Cedar Rapids Sewage Plant prefers Homestead 100% Port Opening Valves



Homestead 100% Port opening Lubricated Valves controlling supernatant, sludge and gas in Cedar Rapids Sewage Plant.

In the transport of sludge and grease from settling basins, full pipe area lines are essential to long pump life. That's why Howard R. Green Company, Engineers, specified 95-4″, 15-6″, and 9-8″ Homestead Lubricated Plug Valves in this Iowa sewage treatment plant. Homestead's 100% pipe area design guarantees full flow—no restrictions to put a strain on pumps and motors.

Add positive lubrication and sealing, Homestead's leakproof no-stick design, plus minimum maintenance, and you'll know why Superintendent William J. Meaney says, "I'm fully satisfied with Homestead Valves on our lines."

Mail coupon today for Reference Books 39-1 and 1A—a complete library of Homestead Lubricated Plug Valves and their uses.

Please send me complete data on Homestead Lubricated Plug Valves and their suggested uses.

Name..... Title.....

Company.....

Address.....

City..... Zone.... State.....

HOMESTEAD VALVE MANUFACTURING COMPANY
P. O. Box 48, Coraopolis, Pennsylvania

VARIABLE SPEED REDUCES SEWAGE PLANT COSTS

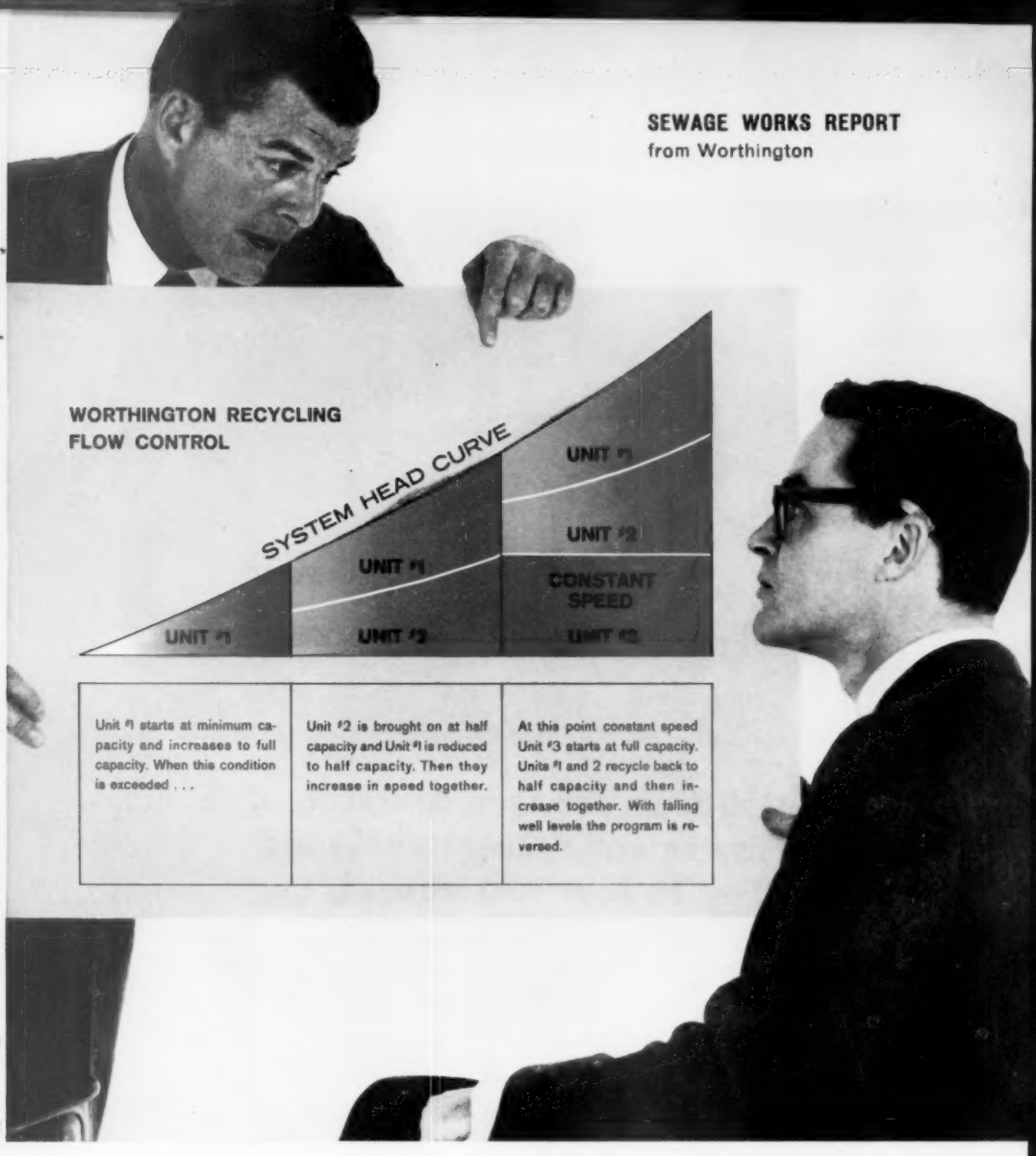
A discussion of the economics of variable speed pumps for sewage works

Why pay extra for variable speed pumping units in sewage plants?

Answer: it saves money in the long run. Here's how: (1) pumping rates are always closely matched to flow, (2) surges are avoided, (3) automatic pumping cuts costs by reducing the number of men needed, (4) the collecting well can be made considerably smaller because it can be designed for average instead of maximum flow.

The system that takes maximum advantage of the possibilities of variable speed operation is Worthington's Recycling Flow Control. Operated by a Worthington engineered control, the system maintains pre-

SEWAGE WORKS REPORT
from Worthington


WORTHINGTON RECYCLING
FLOW CONTROL
SYSTEM HEAD CURVE
UNIT #1
UNIT #2
CONSTANT SPEED
UNIT #1
UNIT #1
UNIT #2
UNIT #3
Unit #1 starts at minimum capacity and increases to full capacity. When this condition is exceeded . . .
Unit #2 is brought on at half capacity and Unit #1 is reduced to half capacity. Then they increase in speed together.
At this point constant speed Unit #3 starts at full capacity. Units #1 and 2 recycle back to half capacity and then increase together. With falling well levels the program is reversed.

cise operation of variable speed pumps.

The float control will handle any number of variable speed and constant speed pumps. How it works in a plant with two variable speed and one constant speed pump is shown above.

The Recycling Flow Control is the latest development of Worthington's continuous work in the public works field. It's another reason that to get the best and the latest you should come to Worthington first. Major public works products include: pumps, comminutors, compressors, engines, and turbines.

If you would like copies of engineering discussions of variable speed pumping for sewage works, write for Bulletins RP-952 and RP-1067. Address Worthington Corporation, Section 105-5, Harrison, N. J. In Canada, Worthington (Canada) Ltd., Brantford, Ontario.

WORTHINGTON

Some of the 69 miles of 24- to 126-inch reinforced concrete pipe needed for the Pittsburgh sewer project.

Pittsburgh chooses concrete pipe for sewer system designed to last 100 years!

The 70 communities of the Allegheny County Sanitary Authority have planned 100 years ahead for their new intercepting sewer system. This big project involves 69 miles of sewers—30 miles in tunnels and the rest open trench construction.

Needed strength, durability and watertightness are assured by concrete pipe. Extensive testing proved these qualities. Total infiltration into the first 31 miles completed was less than 3 gallons per minute. In many of the contract sections total infiltration was found to be zero.

Other communities everywhere are also finding that concrete pipe can be designed precisely to solve their sewer problems. And concrete pipe are readily available. For the giant Pittsburgh project, special casting yards—including all test equipment—were set up at convenient close-in locations to speed up schedules, keep costs low.

Write for free literature. Distributed only in U.S. and Canada.

For the Allegheny County Sanitary Authority: John F. Laboon, Executive Director and Chief Engineer; Lawrence M. Gentleman, Deputy Chief Engineer; Richard J. Dougherty, Construction Engineer.

FOR ALL MODERN PIPELINES
concrete

PORTLAND CEMENT ASSOCIATION
Dept. A9-76, 33 West Grand Avenue, Chicago 10, Illinois
A national organization to improve and extend the uses of concrete

GRAVER
WATER
CONDITIONING
CO.
Division of
Union Tank Car Company

216 WEST 14TH STREET, NEW YOR

V.J.C.-
This may be of
interest to you
H.T.S.

Inter-Organization Correspondence

TO: General Manager

FROM: Technical Director

SUBJECT: Review of Reactivator History

Approaching the 20th anniversary of the Reactivator we would like to summarize briefly its rise to the leading position among solids-contact water clarifiers and softeners. From the beginning, two basic elements were incorporated in the Reactivator design: positive sludge recirculation and mechanical sludge removal over the entire bottom area. Twenty years have confirmed the soundness of these original concepts.

By a constant effort to improve design performance, some important modifications have been made. (1) The method of inducing solids-contact was changed from air to impeller-pump to produce gentle and effective sludge recirculation. (2) The geometry of the machine was modified to get the best conditions for separation of solids from water. (3) Increased knowledge of sludge characteristics led to the redesigning of the sludge removal system.

As a result of these changes the Reactivator is able to provide: (1) solids-contact with the highest concentration of solids for the longest period of time; (2) an increase in throughput rate up to 2½-3 gpm/sq. ft. in certain cases; (3) more reliable and efficient mechanical sludge removal; (4) outstanding surge-proof characteristics.

Probably the most significant work in our program to improve the machine has been our very extensive field studies. We have had the opportunity to work with units from 8 to 125 ft. round and square on applications as widely divergent as...clarifying Arctic tundra lake water...softening and clarifying Mississippi and Colorado River waters...reducing color in Louisiana bayou water...treating hard, clear midwestern deep well supplies, and many more. The complete story of these applications is contained in our new Reactivator Bulletin WC-103C.

The sum total of our experience and knowledge has gone to make the present-day Reactivator the most versatile and reliable solids-contact unit on the market. It is gratifying to all of us to have participated in the development of such a machine.

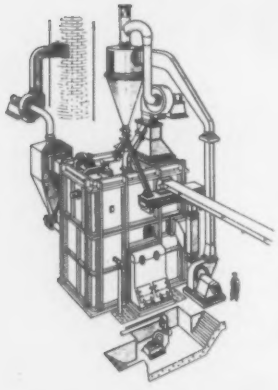
M.L.

ML/lz

Technical Director

WASTE DISPOSAL HAS COST RECOVERY POSSIBILITIES

Why not explore them for your community?



FOR SLUDGE DISPOSAL

THE C-E RAYMOND FLASH DRYING AND INCINERATION SYSTEM

is the only system that permits both drying and incineration of sewage sludge — separately or together — in any proportion. This service-proved equipment today processes more filter cake than all other systems combined. High temperature deodorization and efficient fly ash collecting equipment assure that nearby residents are not bothered by air pollution. The C-E Raymond System's unique design and control also assure economy of operation and uniformity of product.

COMBUSTION

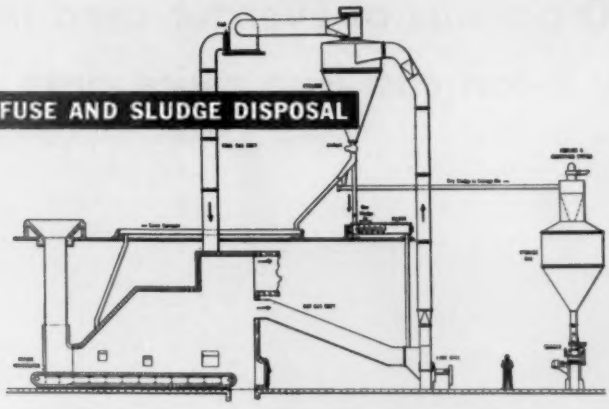
Combustion Engineering Building

Raymond Division: 1132 West Blackhawk Street, Chicago 22, Ill.

Canada: Combustion Engineering-Superheater Ltd.

ALL TYPES OF STEAM GENERATING, FUEL BURNING AND RELATED EQUIPMENT; NUCLEAR REACTORS;

FOR REFUSE AND SLUDGE DISPOSAL



THE C-E INCINERATOR STOKER AND THE C-E RAYMOND SYSTEM

combine a half-century of experience in burning all kinds of conventional, marginal and waste fuels with the most service-proved drying system. Using "continuous" processing, the C-E Incinerator Stoker requires only minimum operating attention and maintenance. From the time refuse is fed into the self-sealing, non-clogging hopper, until the incinerated residue is discharged to the ash pit to be hauled away, the entire operation is automatic, efficient, quick and clean. The C-E Incinerator Stoker is capable of burning all types of combustible refuse in quantities ranging upward from 50 tons per 24-hour day. Heat from the burning refuse is used by the C-E Raymond Flash Dryer System to dry sewage sludge.

Yes, even waste disposal can be turned into a *productive* function. Municipalities all over the country find new economies . . . new revenues . . . through their use of Combustion units like those shown on these pages. With continuous, near-automatic processing, substantial manpower can be diverted to other duties . . . capacity per dollar of investment is increased . . . usable and marketable end-products are produced.

Many communities turn sewage sludge into a desirable, humus-rich soil conditioner with the C-E Raymond Flash Drying and Incineration System. Often, they can recover a large part of their operating expenses from sale of this conditioner or use it to maintain parks and recreation areas. Other towns use units of the same design to incinerate sludge to sterile ash. These versatile units can produce one or both end-products in any proportion.

For refuse incineration, the C-E Traveling Grate Incinerator Stoker is available. It reduces garbage and refuse to a sterile ash, free from clinkers. The ash is suitable for use as a sanitary land fill for the reclamation of waste land. Where required, the incinerator may be used in conjunction with a C-E Waste Heat Boiler to provide an economical steam source for plant heating or power.

To make the most of existing property, economy-minded municipalities are looking more and more into the possibility of *treating both refuse and sewage sludge* at the same plant site. Aside from the obvious benefit of lower capital investment, there's the added benefit of being able to combine both manpower and equipment, eliminating costly duplication. In addition, the C-E Refuse Incinerator can readily supply *no-cost heat* to dry the entire output of sewage sludge.

ENGINEERING

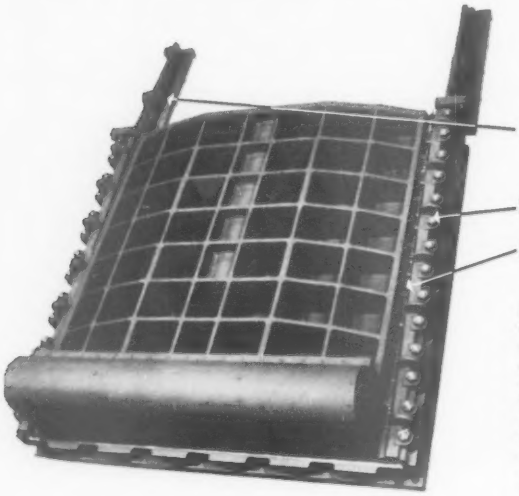
200 Madison Avenue, New York 16, N. Y.
Western Office: 510 West Sixth Street, Los Angeles 14, Calif.

C-E

C-215-A

PAPER MILL EQUIPMENT; PULVERIZERS; FLASH DRYING SYSTEMS; PRESSURE VESSELS; SOIL PIPE

2,300 pounds of Everdur used in new 8-ton cast-iron sluice gate



1 ¾" x 3" Everdur facing strips for gate leaf and frame.

2 1½" Everdur bolts and nuts.

3 Everdur adjusting bolts for cast-bronze wedges.

More than a ton of Everdur was used for facing strips and fastenings in this 8' x 8' sluice gate leaf and frame assembly designed and furnished by the Coldwell-Wilcox Division of Krajewski-Pesant Mfg. Corp., New York City. Consulting engineers, Gannett Fleming Corddry & Carpenter, Inc., Harrisburg, Pa.

This direct-pressure type sluice gate is one of two recently installed by Empresa de Energia Electrica at the Quebradona Dam in Columbia, South America, to regulate the flow of potable water to the city of Medellin.

The 100-foot head of water behind the dam exerts 450,000 pounds pressure on each 8 x 8-foot gate. Everdur* (copper-silicon alloy) was selected to seal against this load because of its high strength and corrosion resistance—plus ready workability and weldability. Sewage treatment and water works equipment of Everdur has been in service without replacement for a quarter century and longer.

Write for Publication E-11, "Everdur Copper-Silicon Alloys for Sewage Treatment and Waterworks Equipment"—or for technical help in selecting the correct material for your job. Address: The American Brass Company, Waterbury 20, Conn. In Canada: Anaconda American Brass Limited, New Toronto, Ont.

*Reg. U.S. Pat. Off. 57133

EVERDUR Anaconda's Family of Copper-Silicon Alloys
MADE BY THE AMERICAN BRASS COMPANY
STRONG • WORKABLE • WELDABLE • CORROSION-RESISTANT

Continued Success

Orders for the Coilfilter continue to come in for United States and Canadian application. We are presently rounding out a program of shop and office expansion which will help strengthen our position in the Sanitary Field.

Since 1954, we have been studying the basic phenomena involved in Fresh Solids Dewatering, and approximately 50 successful Coilfilter installations have been made utilizing this Process. Our conservative approach has paid off; not only has effective equipment been developed for accomplishing this Process, but we have also learned what pitfalls exist and must be avoided.

The writer traveled to England and Scotland in order to personally check the technical aspects of sludge dewatering and make comparisons with our American practices. As a result of the investigation, a licensing arrangement has been made permitting application of our Coilfilters in countries outside of North America, especially in connection with Fresh Solids Dewatering.

There appears to be a substantial market for our equipment in Canada, and we have therefore purchased a site in Brampton, Ontario, and propose to build a shop and office at this location.

Experimental work on other phases of Sanitary Engineering is continuing, and we hope to be of service to the Field for many years to come.

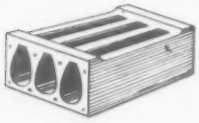
Respectfully,
T. R. Komline

KOMLINE-SANDERSON
ENGINEERING CORPORATION

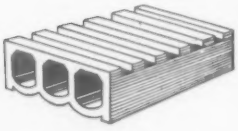
MANUFACTURERS OF THE COILFILTER

PEAPACK, NEW JERSEY

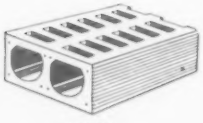
formula for ending stream pollution!



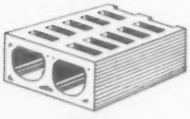
NATCO
Natco Corporation
Pittsburgh 22, Pa.



TRANSLOT
Cannelton Sewer Pipe Co.
Cannelton, Ind.



ARMCRE
Ayer-McCarel Clay Co., Inc.
Brazil, Ind.



BOSCO
Bowerston Shale Co.
Bowerston, Ohio

TRICKLING FILTERS + TFFI UNDERDRAINS = CLEAN WATERS

Trickling Filters' 6 great advantages

Low initial cost, low operating cost and long-term maintenance costs. Overloads are no problem. Give top-notch effluent. Minimum of operating personnel required.

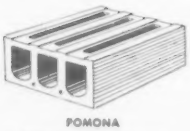
THE MOST IMPORTANT PART

Of a trickling filter is the underdrains. When built of vitrified clay to TFFI specifications they will safely carry highest hydraulic loadings. They alone can withstand all the ravages of acids, alkalis and bacterial action. They are made in modern plants under rigid controls of quality that are impossible with any substitute material. Only they offer you a 50-Year Guarantee against damage by acids and bacteria.

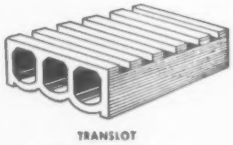
Leaders in ending stream pollution

TFFI members are proud of their part in providing clean waters for America through their contribution of superior vitrified clay filter floors. Over 35% of the population is now served by 2,682 sewage works with trickling filters. This number is constantly growing as more and more engineers discover their superiority.

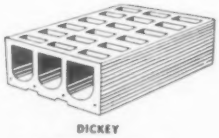
TRICKLING FILTER FLOOR INSTITUTE



POMONA
Pomona Terra-Cotta Co.
Pomona, No. Car.



TRANSLOT
Texas Vitrified Pipe Co.
Mineral Wells, Texas



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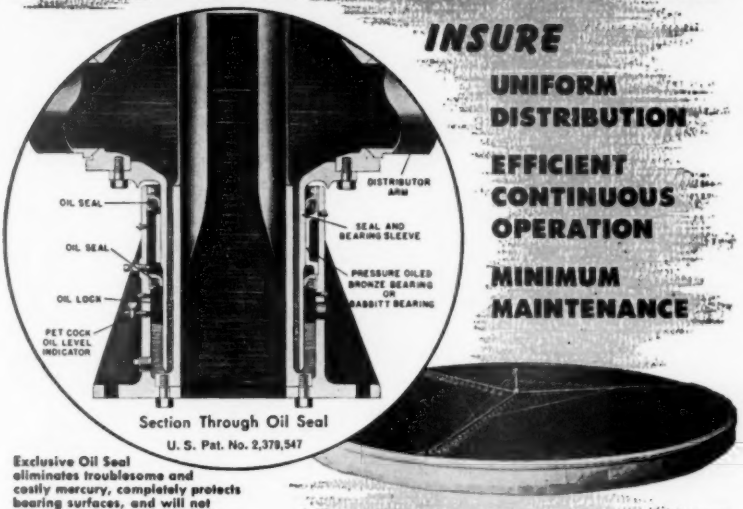

Section Through Oil Seal

U. S. Pat. No. 2,378,547

Exclusive Oil Seal eliminates troublesome and costly mercury, completely protects bearing surfaces, and will not blow out under excessive heads.

Reaction Drive and Positive Drive
ROTARY DISTRIBUTORS

Hundreds of installations have proved the advantages of *American* Rotary Distributors. This approval by consulting engineers is based on economy of initial cost, structural strength and durability, superior liquid distribution, applicability to wide ranges of flow and available head, and minimum maintenance. Inherent design features reduce hydraulic-head losses to a minimum, and provide for maximum utilization of available hydraulic head in performance of useful work. *Every oil seal unit installed has given excellent, trouble-free service!* Available in a wide range of both Reaction-Drive and Motor-Driven Positive-Drive Distributors to meet all variations of actual field conditions—for rapid or standard rate waste filters, sand filters, or for water aeration. *Utilize the experience of American engineers.*

For helpful data and design details, write for Technical Supplement RD

A Complete Line of Pumps and Process Equipment for Sewage and Industrial Waste Treatment.

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AURORA, ILLINOIS

Pumping, Sewage Treatment, and Water Purification Equipment
RESEARCH · ENGINEERING · MANUFACTURING

Offices: Chicago · New York · Cleveland · Cincinnati · Kansas City · Sales Representatives throughout the World

FOR ALUM
liquid or dry

the shortest distance between two points is usually the distance between our plant and you!

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Monroe, La.
New Orleans, La.
Pine Bluff, Ark.
Port St. Joe, Fla.
San Francisco (Port Chicago), Calif.
Savannah, Ga.
Tacoma, Wash.
Vancouver, Wash.
Wisconsin Rapids, Wis.

Check the list of General Chemical's dry or liquid alum producing locations at left. Chances are one is convenient and close to you. In addition to these plants, our chain of warehouses across the country makes stocks of dry aluminum sulfate readily available in every major center of commerce. Write or phone for information on how we can serve you.

Basic Chemicals for American Industry

GENERAL CHEMICAL DIVISION
40 Rector Street, New York 6, N. Y.

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MADISONVILLE, KY., has had no property taxes for three successive years. With this record of efficient management, it is only natural that Clay Pipe should be chosen for the city's new sewerage expansion system. More than twenty-two miles of Vitrified Clay Pipe are going into the project.

Clay Pipe was the natural choice because it does not rust, rot, corrode, or disintegrate . . . never wears out. And new, longer, stronger lengths speed installation . . . cut labor costs.

Only Clay Pipe has *all* the features you can trust.

Public Officials: David Parish, Mayor; A. O. Johnston, Councilman, Chairman of Water and Sewers.

Consulting Engineers: J. Sanders Parker; F. E. Stepp, Resident Engineer.

Contractors: C.F.W. Construction Co., Inc.; Sterrett Construction Co.

C 458-1A

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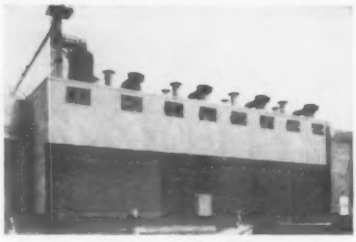

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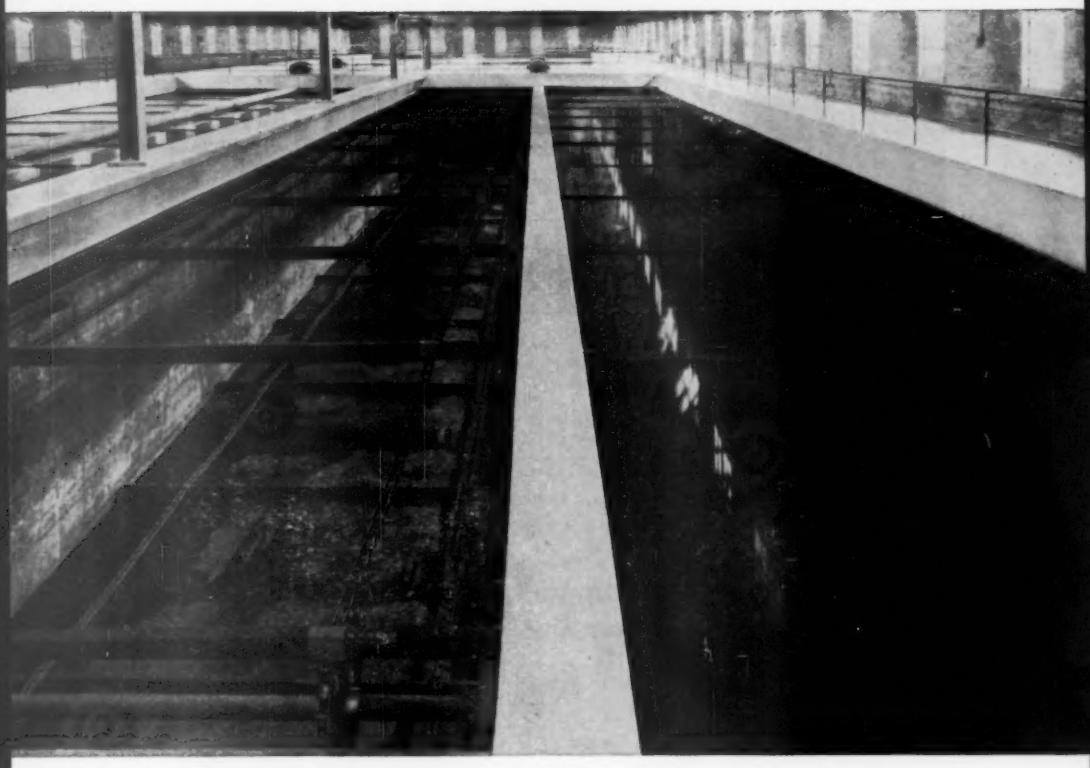

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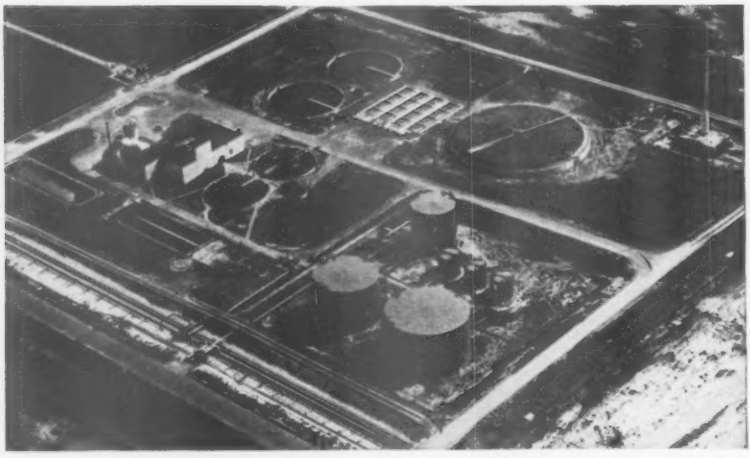

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Sewage Works

MEASUREMENT OF MANNING'S ROUGHNESS COEFFICIENT

By O. John Schmidt

Black & Veatch, Kansas City, Mo.

In the past several years closer attention has been directed toward the hydraulics of sewers, and recent articles and investigations on flows in pipe have brought out data which require thoughtful consideration (1)(2)(3). Although a great deal of data have been gathered in various laboratory studies, information from field investigations has been much more limited. Recognizing the general need for more field data on sewer hydraulics and to obtain current information on the capacity of an important trunk sewer, this investigation was coordinated with a study on a master plan for trunk sewers and sewage treatment facilities for Kansas City, Missouri.

Measurements in Blue River Trunk Sewer

General

In connection with an extensive sewer gaging program which was part of the study, a series of velocity measurements were made in a large trunk sewer built in 1926 and designed to carry both sanitary sewage and storm water runoff. This sewer is called the Blue River trunk sewer. Velocity measurements were made in two separate portions of this trunk, the first at St. John Street and the second at 38th and White Streets. Figure 1 shows the sewer section (Arch Section I) at St. John Street; the section at 38th and White Streets (Arch Section II) has the same general shape with the width also 8 ft-6 in. and the height 8 ft-11¾ in. (6 in. less than for Arch Section I). The Blue River trunk sewer, which was designed to flow full with n value of 0.0115, intercepts dry-weather flow from a population of over 300,000 persons within a net tributary area of 23,726 acres. In the original design and subsequent construction of that part of this sewer in which flows were measured, additional capacity was provided to carry the estimated future flow from the Brush Creek watershed in Kansas. Since complete sewage collection and treatment facilities were provided in this Kansas watershed with no connection

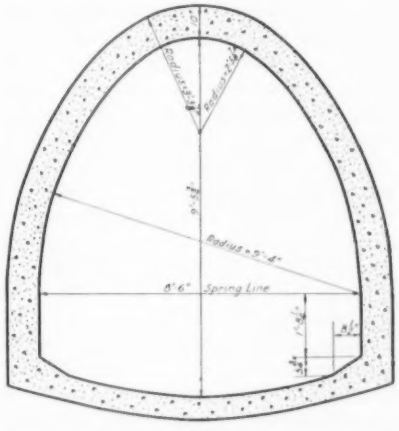

FIGURE 1.—Blue River trunk sewer Arch Section I.

to the Kansas City sewer system, the Blue River trunk sewer, below Brush Creek, has great available capacity. For this reason, even when it is accepting maximum storm flows from tributary main sewers, the Blue River trunk sewer is only about one-half full in the reach considered. Because of this condition it was impossible to measure flows or velocities occurring at depths above approximately one-half full.

St. John Street Reach

The sewer, which was studied in a reach of 947 ft, wherein the invert was originally constructed with a gradient of 0.00088, was carefully inspected for detection of any serious structural flaws. The walls and invert of the sewer were found to be in excellent condition, free from cracks as well as from deposits or slime growths. It is believed that periodic storm flows, carrying appreciable amounts of sand and grit, serve to scour the sewer often enough to prevent growths. The gradient of the invert was established at 50-ft intervals by means of a level circuit. As a result it was discovered that a short section of the sewer near the upper end of this reach was 0.20 ft above the gradient. Repeated observations indicated that although this condition had no measurable effect on depth of flow or velocities at high flows, at low flows a noticeable damming effect was created. For this reason depths and velocities at low flows (under 2 ft of depth) were measured below this obstruction in a reach 797 ft long. Depth measurements at low flows were made at three to five points throughout the reach to establish accurately the hydraulic gradient. At velocities over 4 fps it was impossible to walk in the sewer for any appreciable distance and it was very difficult to measure sewage depths directly. In these cases the distance from the manhole top to the liquid surface was measured. As the distance from the manhole top to the invert had previously been established, the difference was the depth of flow. Sewage depths for high flows were determined at each of the two manholes which defined the 947 ft of sewer studied. There are no other access points to the sewer in this reach. From other depth measurements it was possible to determine that the hydraulic gradient at high flows, for practical purposes, was uniform between the two manholes.

38th and White Reach

Velocity and depth measurements in this portion of the Blue River trunk sewer were made between two manholes 359 ft apart. Original plans showed this sewer to have a uniform gradient of 0.00050. Since the sewer was constructed inside a rock tunnel it was believed that little or no significant changes in the gradient had occurred. A physical inspection of the entire reach of sewer between the two manholes was not made but observations made within the barrel for some distance at each manhole showed the concrete to be in excellent condition. Methods and equipment used for making depth and velocity measurements were the same as those used at St. John Street.

Depth Measurements

Depth measurements were made with an aluminum gaging rod having a cross section of 0.2×1 in. with one knife edge to avoid buildup of water on the rod. A series of check measurements were made which determined that the depth measurements were accurate to within 0.01 ft at low flows and 0.02 ft at high flows. These were made by repetition and observation of the fluctuations of liquid surface. More accurate depth measurements probably could have been made by the construction of stilling wells alongside the main barrel of the sewer. However, neither the time nor the funds available for the study allowed their

construction. The indicated errors in depth measurements are estimated to have affected the corresponding values of $n \pm 0.00003$ and 0.00006 respectively.

Velocity Measurements

Several methods were tried in making velocity measurements. Initially a cup-type current meter was used to measure velocities at 0.2 and 0.8 depth for depths of flow over 1 ft and at 0.6 depth for flows under 1 ft deep, following the recommendations of Pierce (4). This method did not prove to be suitable for the conditions encountered due to the following reasons:

1. Because of the time required to make all readings, there were occasions when the depth of flow varied substantially within the period of measurements.
2. It was found that more than five vertical sections would be required to give the necessary accuracy.
3. Velocity measurements at very low depths or at very high velocities were difficult to make. For these reasons the use of the current meter was abandoned in this study.

The use of dye for measurement of velocity is generally regarded as having only fair accuracy because of the difficulty in noting the end point of passage of the slug of dye and therefore was not considered in this study.

The conductivity method of measuring velocities has been described in the literature for velocity measurements of both water and sewage (5) (6). This method was tried and found to be very satisfactory at flows ranging from 10 to more than 200 cfs. Velocity measurements made with this method are estimated to vary ± 5 per cent from the true values. Essentially, the method involves determination of the mean time of flow of a slug of salt solution or other electrolyte by measuring the sewage conductivity at a downstream point. The instruments and equipment used in this study and shown in Figure 2 are not only inexpensive but simple to set up and operate. The salt initially was prepared in solution form in a barrel and dumped manually into the upstream manhole at a given signal. The time error involved in the introduction of salt was estimated at less than one second. The corresponding error in velocity was inconsequential, being of the order of ± 0.005 fps. It was felt that other factors such as damming by joint material, variations in gradient, and k factor probably had an influence of greater magnitude. The factor

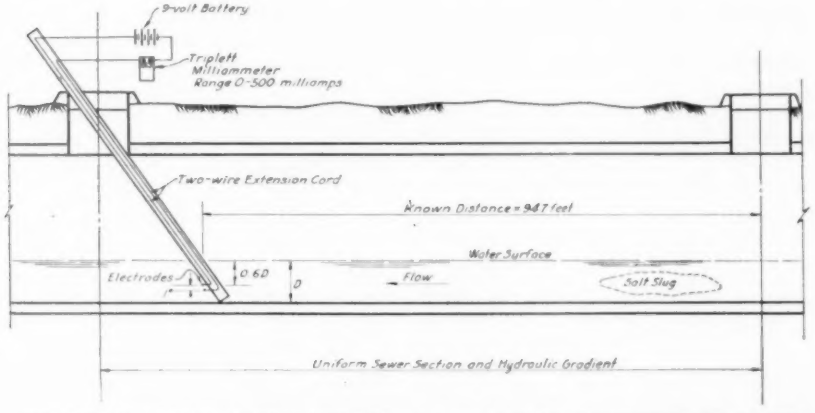

FIGURE 2.—Section showing installation for conductivity measurements in sewers.

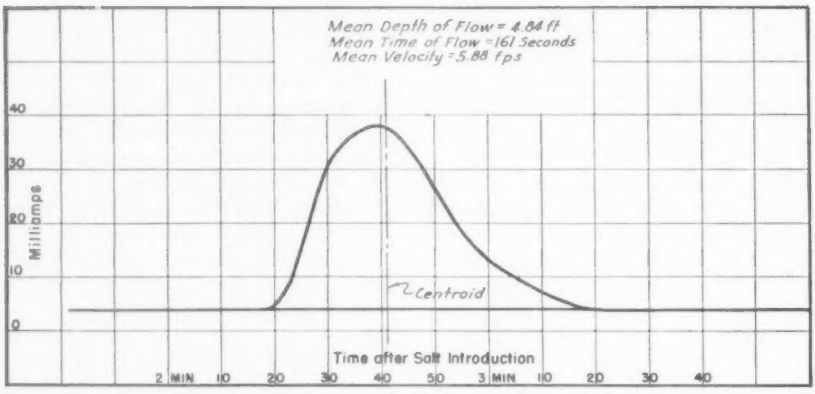

FIGURE 3.—Typical conductivity curve for salt conductivity velocity measurement in Arch Section I, taken at 6:30 PM, Sept. 20, 1957, using 400 lb of salt.

k is a measure of the effective absolute uniform roughness of the interior walls of the conduit. The ratio of r/k, where r is the radius of a circular conduit, is called the effective relative roughness (7)(8). Further experiment revealed that it was possible to introduce the salt directly without making a solution. The salt used was a fine grain variety similar to table salt and went into solution rapidly. This proved to be an advantage in measuring low flows in the St. John portion of the sewer, when the measurements were made over a distance of 797 ft. In these cases the salt had to be carried inside the sewer to the upstream end of this reach before introduction.

Figure 3 indicates a typical curve of increased conductivity caused by the passage of the salt slug. The curves revealed very little "tailing" of the salt solution and showed that the method permitted an accurate determination of the mean time of flow.

Results of Measurements

Table I summarizes the measurements made and gives the corresponding values of Manning's n, which vary with depth of flow. Change in depth of flow in a conduit is accompanied by corresponding changes in the shape of the flow section and the value of the hydraulic radius. Variations in n, as measured here, probably are influenced by the inability of the hydraulic radius term in the Manning formula to show

TABLE I.—Blue River Trunk Sewer Hydraulic Data

Test Number*	Date (1957)	Salt Used (lb)	Length of Reach (ft)	Slope	Mean Sewage Depth (ft)	Hydraulic Radius (ft)	Mean Velocity (fps)	Q (cfs)	Manning's n
1	11/12	40	797	0.00087	1.45	0.96	3.49	33.2	0.0123
2	11/12	40	797	0.00087	1.52	1.0	3.64	36.8	0.0121
3	11/12	40	797	0.000918	1.68	1.1	3.95	45.4	0.0119
4	9/11	300	947	0.000909	3.55	1.97	5.21	147.0	0.0134
5	9/20	400	947	0.000898	4.84	2.30	5.88	224.8	0.0131
6	8/16	100	359	0.00050	2.37†	1.58	2.57	50.4	0.0175

* Tests 1–5 were made at St. John Street. Test 6 was made at 38th and White Streets. Each test was repeated at least once.

† 0.46 ft of grit and silt on bottom; 2.83 ft from liquid surface to invert.

adequately the effect of such change in shape.

Figure 4 shows Manning's n plotted against depth of flow and appears to indicate variation of n with depth of flow. This variation has been reported (2)(5)(7)(9)(10)(11)(12).

Figure 5 shows the hydraulic elements of the section indicating the differences between n constant and n variable.

In applying this chart or similar charts for circular sections it can be seen that for any partly-full flow condition the velocity with n variable is somewhat less than that calculated with n constant. Camp (10) indicates that a velocity of 2 fps is adequate for self-cleansing with an average municipal sewage if the sewer flows more than one-half full. For some wastes velocities below 1.5 fps might cause deposition of sewage solids in the conduit. Once deposited it is doubtful whether velocities of even 2 fps would again bring these solids back into suspension. Deposited solids would be moved along the sewer invert by the tractive force of the water; however they would have a much lower velocity than that for solids carried in suspension. In long sewers this would result in decomposition of solids, creating septic conditions with accompanying hydrogen sulfide problems. Septic sewage is difficult to treat and the presence of hydrogen sulfide can result in deterioration of concrete both in sewers and in other structures.

Most of the hydraulic elements graphs in common use have been prepared on the assumption that the friction coefficient n does not change with the depth of flow in the conduit. For certain critical design conditions this assumption could result in velocities so low that deposition problems might follow.

Data from Test No. 6, shown in Table I, are of considerable interest. This test showed that under existing conditions in this combined sewer de-

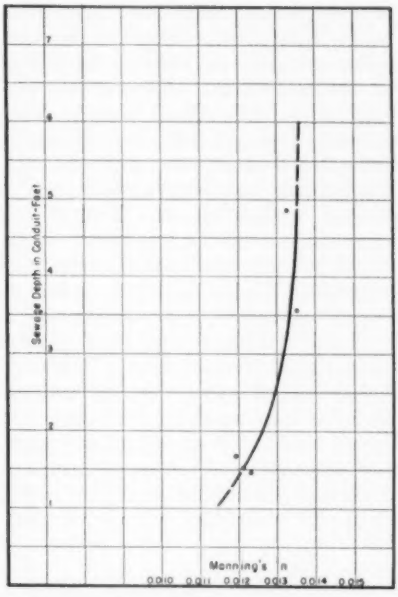

FIGURE 4.—Variation in Manning's n with depth of flow.

posits of grit were found on the invert. In this test over 5 in. of grit, gravel, and sewage solids covered the invert and had a marked effect on the value of n found. This bottom material was so heavy that it remained on the invert even with a mean velocity of 2.6 fps in the sewage above it. Manning's n for this section of the trunk sewer was found to be 0.01745 whereas in the St. John Street section the maximum value of n measured was 0.0134. No deposits were found in the St. John Street section of sewer during the period in which the measurements were made. It is apparent that bottom deposits can be of significant importance in their effect on Manning's n and on the corresponding capacity and velocity in the conduit.

Other Investigations and Data

There are numerous reports on record of determinations of n for a variety of sewer sizes and materials. Of these

determinations, some have been made under field conditions on conduits carrying sewage, while others have been in the laboratory with very carefully laid conduits carrying water. Both sources have yielded data of importance but probably the most applicable information has been obtained from a careful correlation of selected data from both areas of endeavor. Some investigators believe that the rigorously controlled conditions required for accurate laboratory work can rarely, if ever, be duplicated in practice. Others claim that the wide variety of field conditions which affect flow in conduits make it very difficult to obtain accurate results. Both views have merit but thoughtful blending of pertinent data should provide the most useful fund of knowledge on the subject. Data from a few of these studies are given here.

Killam (13) measured velocities in a new 60-in. concrete sewer using dyes and surface floats and concluded that n should be not lower than 0.014. Weller (14), using a current meter to measure velocities in several brick sewers, found n values which ranged from 0.0133 (77-in. sewer) to 0.0103 (70-in. sewer). In a 21-in. vitrified clay sewer, he determined n to be 0.0156. Johnson (5) used dyes and the conductivity method to measure n in several large concrete sewers having egg- and basket-shaped sections and found n to vary from 0.0135 to 0.0144. Cosens (15) measured n in two 8-in. sewers, one of asbestos-cement and the other of vitrified clay pipe. He stated a belief that after several years of use the sewers would tend to become coated with slime or grease and the coefficient of roughness of such sewers would actually measure the effect of such coatings. From this he felt that regardless of the structural material the value of n would tend to approach the same figure for any given slope, depth of flow, and pipe diameter. He stated that the coefficient for design should be 0.012 or 0.013.

Additional investigations should be made to measure n under the actual conditions which exist in both sanitary and combined sewers. Sewers are seldom installed under ideal conditions.

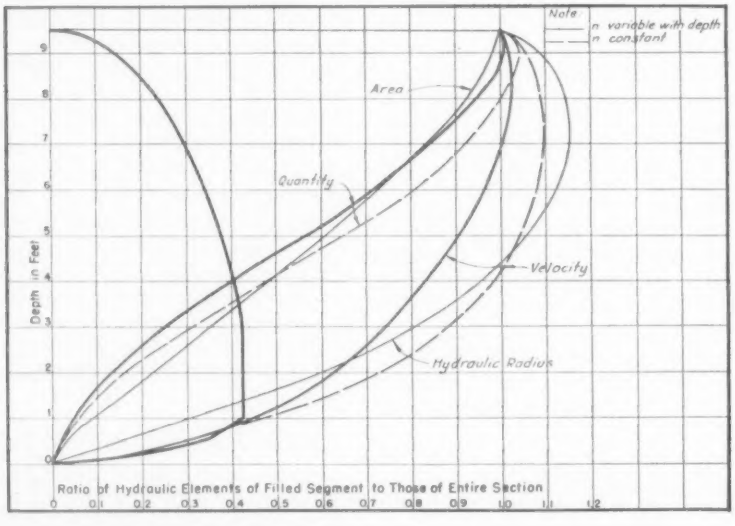

FIGURE 5.—Hydraulic elements of sewer with Arch Section I.

TABLE II.—Suggested Values of n for Manning's Formula in Sewers

Conduit	n	
	Min*	Max
Asbestos-cement	0.012	0.015
Corrugated steel, uncoated, ½-in. corrugations	0.024	0.026
Corrugated steel, asphalt coated and 25-per cent paved	0.021	0.023
Corrugated steel, smooth asphaltic lining	0.012	0.015
Cement-lined cast iron pipe	0.012	0.015
Dirty or tuberculated cast iron pipe	0.015	0.035
Concrete pipe	0.012	0.015
Vitrified clay pipe	0.012	0.015

* Values for clear water.

There are a number of reasons for this. Some of the disturbance factors which influence the loss of head and therefore the values of n are given in the recent sewer design manual (9) and repeated here:

1. Rough, opened, or offset joints.
2. Poor alignment and grade due to settlement or lateral soil movement.
3. Deposits in sewers.
4. Coatings of grease or other matter on interior of sewer.
5. Eddying and deposits of solids caused by enlargements at manholes and junction chambers.
6. Tree roots, joint compounds, mortar dams from careless jointing, and other protrusions.
7. Flow from laterals, disrupting flow calculations (In combined sewers, laterals and connections to the main sewer all discharge simultaneously during rainfall).

In sewers containing much curvature n is said to increase on curves by an amount of about 0.003 to 0.005 (16). Suggested values of Manning's n are given in Table II.

Basic Hydraulics

The experimental work on artificially roughened pipe done by Nikuradse (17) has become a standard reference in many technical presentations of hydraulic hypotheses on conduits flowing full. Figure 6 from his data shows the friction factor f plotted against the Reynolds number. The diagram shows three general regimes of flow in terms of Reynolds numbers: laminar, up to 2,000; partly turbulent from 2,000 to about 4,000; and turbulent above 4,000. The type of roughness studied by Nikuradse was made homogeneous whereas the irregularities on the walls of commercial pipe are non-uniform in character. Studies on flows in such commercial pipe have produced data not entirely in conformance with Nikuradse's curves (1)(3). Mathematical formulas have been developed for the Darcy-Weisbach friction coefficient f expressed in terms of the Reynolds number and the effective relative roughness r/k, where r is the radius of a circular conduit and k is the effective absolute roughness coefficient. These formulas vary according to the three regimes of flow. The Nikuradse formula for turbulent flow is

$$\frac{1}{\sqrt{f}} = 1.74 + 2 \log \left(\frac{r}{k} \right) \ldots . (1)$$

and does not contain the Reynolds number. Rouse (8) (18) has shown that the Manning formula

$$V = \frac{1.486}{n} r^{2/3} s^{1/2} \ldots . (2)$$

does not have the accuracy of Equation 1, especially when dealing with conduits having n values which fall at either end of the range commonly used. This may be the reason for the results obtained in certain investigations of n. Straub and Morris (1) in studying commercial concrete pipe reported an increase in n with an increase in conduit size. (In current design practice the value of n is reduced when the conduit size is increased and the same pipe material used.) Moreover, they

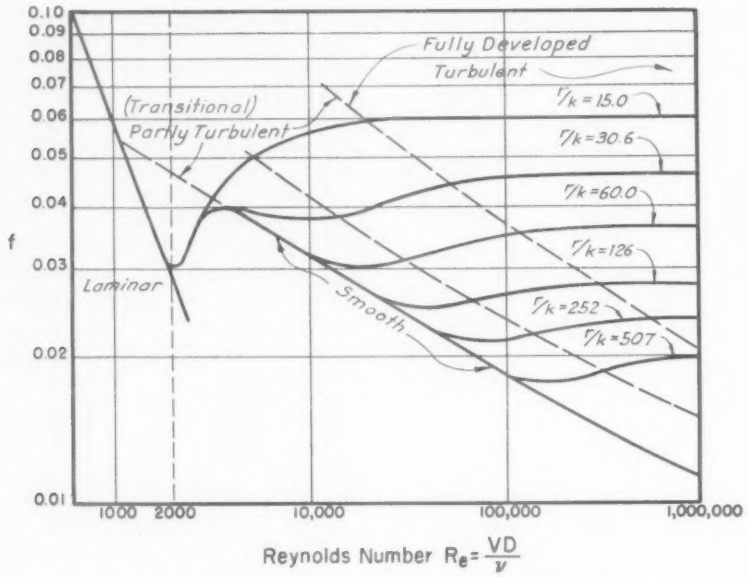

FIGURE 6.—Variation of f with Reynolds number for smooth and artificially roughened pipes (taken from data of Nikuradse (17)).

reported that there appeared to be a functional dependence of the friction factor on both the Reynolds number and the relative roughness r/k, implying that the flow regime is transitional between partial and full turbulence. In addition they found k to increase with the Reynolds number for a given pipe and to increase with the size of pipe. However, they concluded that the mathematical equations of Nikuradse were inadequate to describe the conditions found in their investigation, nor was the factor k satisfactory as a representative length parameter for flow in the pipes studied.

These recent studies indicate an uncertainty as to exactly how Manning's n varies with conduit size, and also imply that sewage flow in conduits may not always lie in the fully turbulent range. On the other hand, the traditional empirical pipe design formulas do not include the Reynolds number and thereby implicitly assume fully turbulent conditions. These differences point toward a need for further investigation along these lines.

Conclusions

1. Variations in Manning's n occur with changes in depth of flow in sewers. For certain sewer designs such variations can be important.

2. A number of conditions brought about during construction of a sewer or which can occur afterwards, can change the value of n from that used in the design of the sewer.

3. Bottom deposits or other conditions which greatly alter the invert surface of the sewer probably cause a greater variation in n than that caused by changes in depth of flow.

4. Past laboratory experimental work on Manning's n has been valuable but there is need for much more work to determine the value of n under actual field conditions. Thoughtful combination of data from both sources should prove useful in future design work.

5. Further investigations should be

made to: (a) remove the uncertainty as to how Manning's n varies with conduit size, if k is assumed constant; (b) examine the suitability of the parameter k for the various flow conditions experienced in the field; and (c) determine more exactly the regimes of flow encountered by sewage flow in conduits.

6. The method described here to measure mean velocity is regarded as simple, accurate, inexpensive and, in certain cases, far easier to use than more conventional procedures.

Acknowledgment

Valuable assistance was given by L. McNeill and T. R. Higbee in carrying on the field work; by F. L. Truman in providing the necessary instrumentation; and by P. D. Haney and Dr. J. S. McNown in reviewing this paper.

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EVALUATION OF FROTHING IN SEWAGE TREATMENT PLANTS *

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The principal factors that have been given consideration in relation to frothing in aeration tanks in sewage treatment plants are:

1. The presence of surface active agents.

2. The effects of suspended solids concentration in the mixed liquor. Low suspended solids concentrations are usually associated with greater frothing tendencies. However, there are indications that the concentration level of suspended solids necessary to control frothing varies widely. A concentration level which may apply in one instance may be inadequate in another.

3. The presence or absence of naturally occurring anti-foam substances such as oils and greases, as well as salts of fatty acids, all of which in the opinion of some investigators serve as inhibitors to froth formation. It has been noted that frothing is more likely to occur at the effluent end of aeration units and progressively less towards the influent end. It is postulated by some that the reason for this is that the anti-foam substances lose their effectiveness as they are stabilized in passing through the aeration units. In fact, this observation has been put to practical use in some instances in which it has been reported that raw sewage may be used with success as a defrother, and as reported by Mau (1) certain sewage treatment plants in Germany minimized frothing by adding raw sewage along the entire length of the aeration tanks.

4. The formation of foam stabilizers by the biological floc in the aeration process. Although this has been postulated and although frothing appears to vary with the oxidative process in the aeration tanks, the production of a specific stabilizer has not been established.

5. Aeration rates. In general, it has been observed that the severity of frothing, or accumulation of foam on aeration tanks is related positively to aeration rates.

In addition to these factors, general observations have been made by some investigators relating the variations in frothing to such factors as pH, time of day, dissolved oxygen concentration, sludge age, strength of sewage, and certain meteorological conditions.

It has been noted that wide variations in frothing occur, not only from plant to plant, but also within a single plant operating under apparently similar conditions.

The evaluation of these various factors is complex. Yet if variations in frothing are to be accounted for, at least the foregoing factors must be considered. It will only be through an undertsanding of the influence of these factors that a rational approach may make possible the control of frothing through operational procedures.

* Presented at the 31st Annual Meeting, Federation of Sewage and Industrial Wastes Assns.; Detroit, Mich.; Oct. 6–9, 1958.

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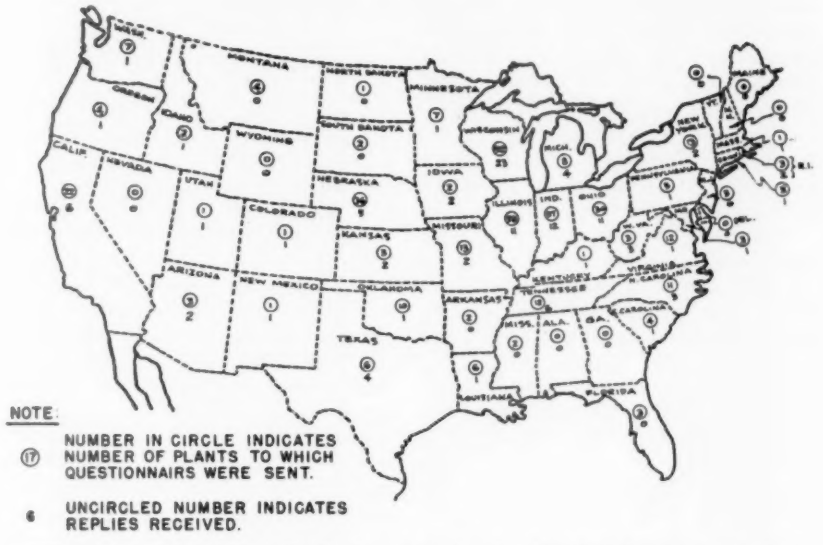
NOTE:
(17) NUMBER IN CIRCLE INDICATES NUMBER OF PLANTS TO WHICH QUESTIONNAIRS WERE SENT.
6 UNCIRCLED NUMBER INDICATES REPLIES RECEIVED.

FIGURE 1.—Geographical distribution of results of activated sludge treatment plant questionnaire survey made in April 1956.

Questionnaire Survey

In order to obtain further background information, a questionnaire survey of activated sludge sewage treatment plants in the United States was made.

The questionnaire was sent to 398 aeration-type sewage treatment plants. Figure 1 is a map showing the distribution of the questionnaire and replies received.

Data were obtained from 74 diffused-air and 30 mechanical aeration type plants. Ninety-seven of the replies

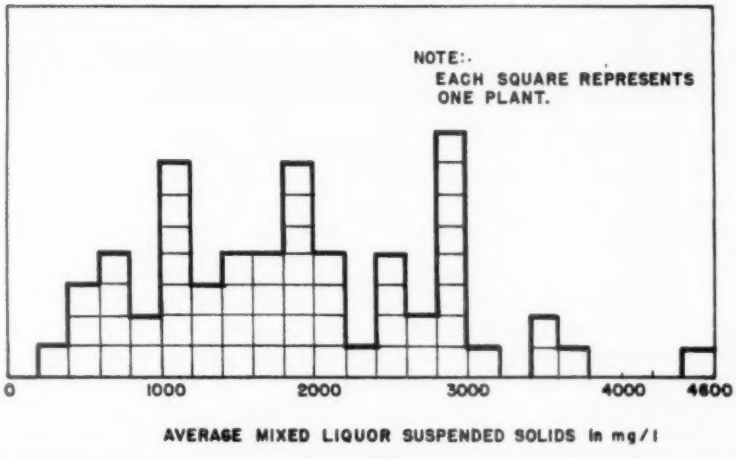

FIGURE 2.—Mixed liquor suspended solids concentration and frothing occurrence taken from questionnaire survey

stated that frothing was present to some degree and four indicated no frothing. Fifty plants reported that frothing was a daily occurrence, while 39 indicated that it was not.

The survey further indicated that frothing occurs over a wide range of mixed liquor suspended solids, as shown in Figure 2.

A majority of the operators noted that greater frothing occurred under reduced suspended solids concentrations and with increased rates of aeration. This is evident from Table I.

TABLE I.—Frothing Results Associated With Various Activated Sludge Operating Procedures

Action or Reason	Result (No. of Plants)		
	Froth	Less Froth	More Froth
Increased suspended solids	—	14	—
Decreased suspended solids	—	—	49
Increased aeration rate	—	—	18
Decreased aeration rate	—	2	—
High dissolved oxygen	2	—	—
Excess digester supernatant	1	—	—
Increased detention time	1	—	—
Increased sludge age	1	—	—

Of the treatment plants reporting on the plant efficiency during periods of frothing, 80 per cent reported there was no change. This is shown in Table II.

Reports on the daily occurrence of frothing indicate the preponderance of frothing on Sunday, Monday, and Tuesday. With regard to time of day that frothing occurs, it is noted from Table III that frothing occurs most frequently during early morning hours.

Froth Measurement

Although the survey data and other reports contain qualitative information regarding the frothing tendencies of mixed liquors, there is need for a quantitative measurement.

Two methods of foam measurement were used in the frothing studies.

TABLE II.—Effect on Plant Efficiency During Frothing

No change	58
Higher efficiency	4
Decreased efficiency	1
BOD of effluent higher	3
Suspended solids of effluent higher	8
Rising final sludge	1

"Dynamic" measurements were taken of the froth while the froth is formed whereas the "static" measurements were taken after the froth had been produced. The dynamic froth measurement is used by others in related fields and the method was adapted to the measurement of froth in sewage and sewage-sludge mixtures (2)(3).

The dynamic method more nearly represents conditions in the aeration tanks at sewage treatment plants where the froth forms and continues to build up until the rate of breakdown or decay of the froth is equal to the rate of formation. The dynamic method

TABLE III.—Time at Which Frothing Occurs

Time of Day	Number of Occurrences
Midnight	5
1 AM	6
2	7
3	8
4	10
5	11
6	13
7	12
8	11
9	10
10	7
11	5
Noon	5
1 PM	4
2	1
3	1
4	0
5	0
6	0
7	1
8	1
9	1
10	2
11	3
All hours	1
Night	9
Early morning	13
Mornings	5
AM	12
Cool mornings	2

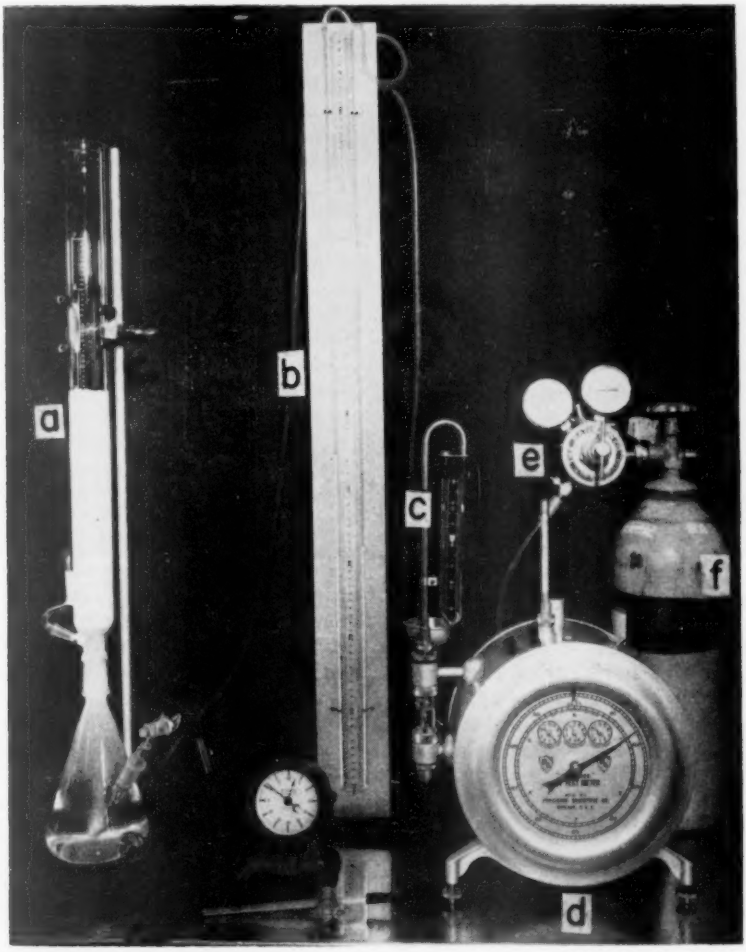

FIGURE 3.—Complete foam measurement assembly. Component parts as follows: (a) foam meter, (b) flow-rate manometer, (c) gage pressure manometer, (d) gas totalizer—wet test meter, (e) air regulatory valve, and (f) air cylinder.

used in these studies was based on this principle, under conditions which permit measurement of the aeration rate and volumes of foam formed.

The dynamic foam measurement used measures the average lifetime of a bubble in the foam. This value is denoted by Σ. This foam measurement was made in a specially designed foam meter shown in Figure 3 along with other necessary component parts.

The essential parts of the foam meter are an extra coarse 12-mm OD fritted glass gas dispersion cylinder, a 1-liter Erlenmeyer aeration flask to contain the sample, with inlet and drain, and a column for accumulating the foam and for measuring the resulting foam volumes. A manometer attached to the side of the foam column permits measurements of foam density if large quantities of foam are produced.

The essential parts of the complete apparatus are the foam meter, a calibrated air-water orifice manometer to regulate air flow rates, a mercury manometer for gage pressure air-volume corrections, a wet test displacement meter for measuring the total quantity of air supplied, a needle valve for regulation of air flow rates, and a compressed air cylinder as an air source.

The static foam measurement used was simple and influenced little by human error. In the static method, the foam may be formed by bubbling gas through the liquid, whipping the liquid, or by other agitation and air entraining methods. After the foam has formed, observation of the time interval for collapse of the foam is made. The measured time interval is denoted as "persistency." The method used may provide an easy method for plant operators to take quantitative data of the frothing conditions in their treatment plants.

Some typical results of foam measurements corresponding to frothing conditions that existed at a sewage treatment plant are shown in Figures 4 and 5.

As has been noted previously, one of the factors associated with frothing is the concentration of suspended solids in the aeration tanks, where it is frequently noted that smaller quantities of foam are produced in the presence of high suspended solids than with low suspended solids. Therefore, it would be expected that the measurement of froth would be influenced by suspended solids concentrations of the mixed liquors tested.

In all instances with higher suspended solids concentrations for a given sample of mixed liquor the value of Σ and persistency were lower.

Studies of Organic Solutions

Initially studies were made using solutions of known composition to determine the effect of organic substances in synthetic sewage on frothing, with and without alkyl benzene sulfonate.

FIGURE 4.—Froth conditions at sewage treatment plant for following conditions: time, 8:30 AM, Σ, 11.3 sec, persistency, 20 sec, and suspended solids, 380 mg/l.

FIGURE 5.—Froth conditions at same sewage treatment plant for following conditions: time, 9:45 AM, Σ, 0 sec, persistency, 2 sec, and suspended solids, 310 mg/l.

In the first series, a concentration of 10 mg/l of ABS was used in combination with organic and inorganic compounds. The solutions were tested in aeration columns. In summary, these studies indicate that the presence of 10 mg/l ABS enhanced the frothing ability of organic solutions as evidenced by the volumes and lifetimes of the foams produced. However, for all solutions containing 10 mg/l ABS, the volumes of foam produced varied markedly with differing combinations of organic substances. Combinations of bacto-peptone and beef extract in the presence of ABS generally produced more stable foams. Various combinations of the organic solutions tested have the ability to froth without ABS, but to a lesser extent. Similar results were obtained when the concentrations of organic compounds were reduced 90 per cent both with and without the presence of 10 mg/l ABS, but the maximum volumes of foam produced were generally less when compared with the results of the full strength solutions.

A free ABS concentration of 10 mg/l is an unusually high value to expect at present in sewage treatment plants; consequently studies were conducted at reduced concentrations to determine the concentration level necessary to induce a marked increase in frothing. The concentrations of bacto-peptone were varied also and tested. The froth measurements, persistency, and average lifetime of the bubble were used in these studies. It was noted that the frothing ability of the solutions increased markedly at concentrations of 3 mg/l and greater of ABS in the presence of 300 mg/l bacto-peptone, as compared to solutions with concentrations of less than 3 mg/l ABS. Similarly, it was noted that the frothing ability increased markedly at concentrations of 15 mg/l and greater of bacto-peptone in the presence of 3 mg/l ABS. This concentration of bacto-peptone corresponds to an organic nitrogen concentration of 2.5 mg/l. The results

of the latter study are shown in Figure 6.

Fractionation and Analyses of Foams

The fractionation of foam or measurement of accumulations in foam has been used by investigators for finding the compound or compounds responsible for the foaming capacity of a solution.

Preliminary investigation in these studies revealed an accumulation of organic nitrogen as well as ABS in the froth. Consequently, it was considered desirable to analyze the froth for organic nitrogen compounds.

Studies were made in the laboratory, and analyses were made also of the foam collected from the aeration tanks at sewage treatment plants. In addition to total organic nitrogen, surface tension, pH, and persistency, foam density measurements were made at intervals throughout a 70-min aeration period.

Samples containing 200 mg/l beef extract, 300 mg/l bacto-peptone, 50 mg/l urea, and 10 mg/l ABS in tap water were placed in aeration tubes. Each tube was aerated at the same rate and samples of froth as well as samples of bulk were withdrawn from the first aeration tube for pH, surface tension, total organic nitrogen, and foam measurements. The samples withdrawn from the first tube were replaced with solution from the second tube, and similarly the second tube depletion was replaced with solution from the third tube. Consequently, the depletion of aeration liquid occurred in the fourth tube which minimized depletion effects in the sampling column. Samples of froth and aeration liquid were withdrawn simultaneously at various intervals during the aeration period.

The results as presented in Table IV indicate:

1. An increase in surface tension from 45.8 to 66.1 dynes/cm occurred in the aeration liquid.
2. An increase of pH from 7.7 to 8.1 occurred in the aeration liquid.
3. A slight decrease in total organic nitrogen in the aeration liquid occurred.
4. The total organic nitrogen content of the liquid of froth remained approximately at the same concentration (140 mg/l) for the first 35 min and then increased to 254 mg/l at 70 min aeration time.
5. The Σ_o values of the aeration liquid approached infinity and remained high throughout the first 35

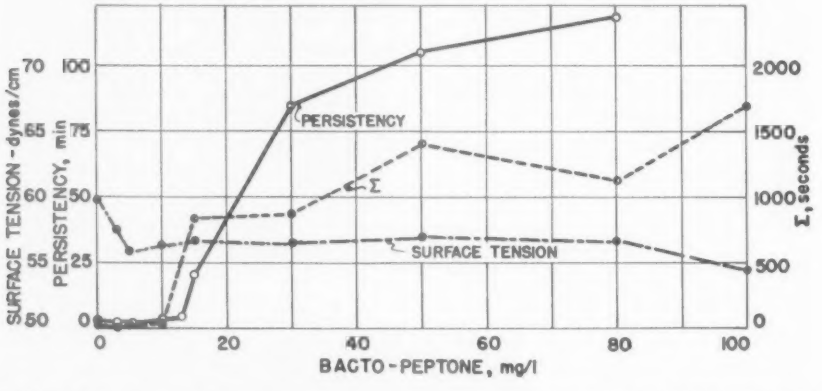

FIGURE 6.—Effect of bacto-peptone on froth formation in tap water with 3.0 mg/l alkyl benzene sulfonate.

TABLE IV.—Analyses from Froth Produced in Laboratory During 70-min Aeration Period

Time of Sampling, from Start (min)*	Surface Tension (dynes/cm)	pH	Total Organic Nitrogen (mg/l)		Increase of Total Organic Nitrogen in Froth over Bulk (per cent)	Σ_c (sec)	Σ (sec)	Density† $[\rho]$ (g/ml)
			Bulk	Froth				
0 (Tube 1)	45.8	7.7	81.5	—	—	∞	—	0.0133
0 (Tube 2)	46.1	7.75	82.5	—	—	12,700	—	0.0127
0 (Tube 3)	41.1	7.75	87	—	—	∞	—	0.0146
0 (Tube 4)	47.3	7.75	85.2	—	—	∞	—	0.0112
5	47.5	7.80	90.3	143	58	18,200	—	0.0103
10	49.7	7.75	87.0	138	57	5,060	—	0.00565
15	50.0	7.8	84.0	153	82	8,000	—	0.00757
25	54.9	7.9	85.2	127	49	∞	—	0.00483
35	56.5	7.95	82.8	148	78	‡	—	0.0022
45	60.8	8.02	82.8	174	111	—	36	§
55	64.7	8.07	81.6	196	140	—	22	§
70	66.1	8.1	79.2	254	221	—	14	§

* Froth-producing medium made from 200 mg/l beef extract, 300 mg/l peptone, 50 mg/l urea, 10 mg/l ABS, and tap water.

† Density of foam $[\rho] = \frac{\rho v_l}{v}$ where ρ is the density of the liquid; v_l is the volume of liquid in a volume of foam v.

‡ Error in measurement.

§ Unable to determine.

min of aeration, after which they dropped markedly to approximately 20 sec for the remaining aeration period.

6. The density of the froth decreased throughout the aeration.

The marked increase of total organic nitrogen accumulation in the froth occurred at nearly the same time as the drop in the frothing parameter. Apparently fractionation by foaming occurred with a removal of the ionic or molecular species having the greatest frothing tendency during the first 35-min aeration interval, after which, either by change in composition or concentration of the first frother, the second frother accumulated in the liquid of the foam, in this case, additional compounds containing organic nitrogen. The steady increase in surface tension in the bulk was evidence that there was a depletion of the surface active material in the bulk solution and ABS was accumulating in the foam which was being removed.

The analyses of samples of foam collected at sewage treatment plants have shown accumulations of ABS in the foam liquid in concentrations ranging from 950 to 2,630 mg/l. Total organic nitrogen concentrations in the foams ranged from 139 to 371 mg/l. After dialysis of the foam liquid, approximately 63.5 per cent of the ABS was retained and approximately 50 per cent of the total organic nitrogen was retained. Assuming that the total organic nitrogen retained represented protein and degraded protein, the weight ratio of ABS to protein-like compounds was 1.5:1. The retained ABS may have been associated with the proteins and higher peptides possibly bound by the dissociating side chain amino groups of proteins (4).

Frothing in Mixed Liquors

Test Procedure

As part of the research program a survey of five activated sludge sewage treatment plants was made during periods of high and low hydraulic and organic loadings. As a result of this survey it was concluded that in con-

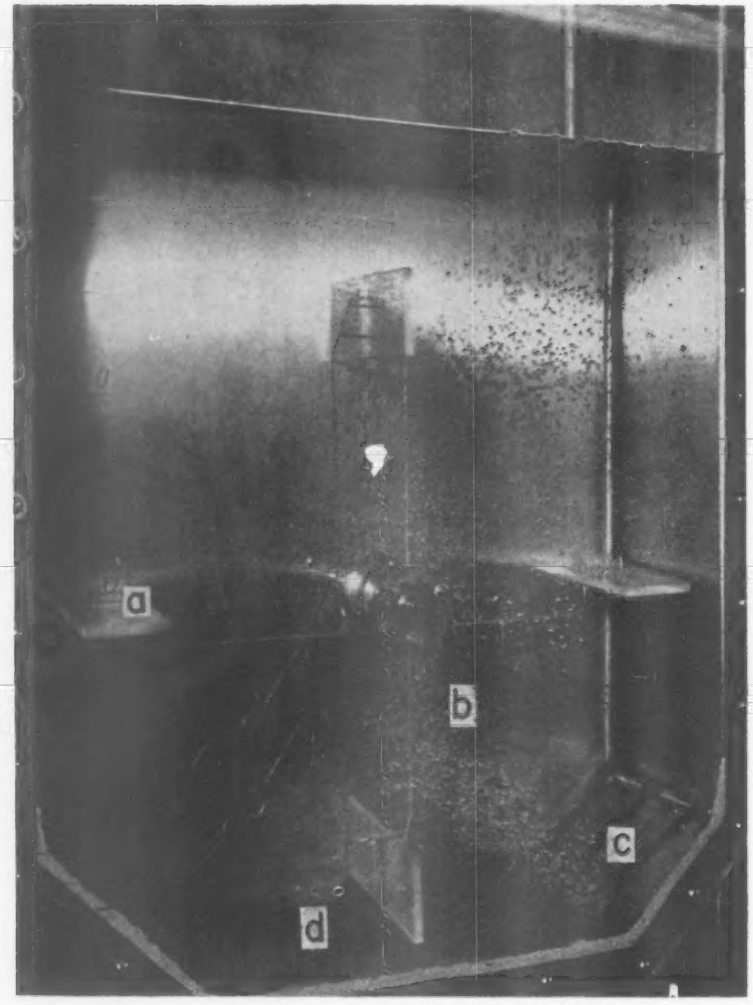

FIGURE 7.—Laboratory aeration tank for batch activated sludge studies. Parts as follows: (a) rotating baffle, (b) air bubble pattern, (c) spherical diffuser stones, and (d) sample opening and drain.

sidering the anionic detergent ABS, the evaluation of this substance as a frothing factor should be based on the amount that is in the unassociated or free state rather than on the amount adsorbed or associated with the particulate matter. A second observation from these studies was that the free ABS concentrations, in mixed liquors, of two plants tested, was higher near the effluent end of aeration tanks than near the influent end.

Based on these earlier investigations a more complete study was made of the factors related to frothing of mixed liquors. This was accomplished in extensive laboratory studies as well as from surveys of four activated sludge-

sewage treatment plants in Wisconsin and the data were analyzed by statistical methods.

The froth parameters, persistency and the average lifetime of a bubble in the foam, Σ, were made of the mixed liquor samples along with quantitative measurements of ABS, ammonia nitrogen, organic nitrogen, electrode potential, pH, suspended solids, temperature, and BOD.

The laboratory apparatus used is shown in Figure 7. The batch units were designed to avoid overaeration of the mixed liquors under test by the use of mixing baffles to keep the particulate matter in suspension while aerating at rates coincident with treatment practices. The units were of 50-liter capacity to avoid the effects of sampling depletion.

The mixed liquors used in the units were obtained from the Madison Nine Springs Sewage Treatment Plant. Mixed liquor suspended solids concentrations, ABS, ratios of digester supernatant to settled sewage volumes, and rate of aeration were varied at three different levels. Samples for analysis were taken from each unit every hour over a six-hour aeration period.

From the field investigations at the sewage treatment plants random samples were taken from the aeration units and analyses were made.

In total, 104 simultaneous sets of observations of the measured factors were obtained.

Correlation of Results

The results of these studies were statistically analyzed both by simple and multiple correlation techniques using an IBM 650 computer. The multiple correlations are particularly useful in that a single factor can be assessed independently of the remaining factors.

The results showed that approximately 60 to 70 per cent of the variation in the froth parameters was accounted for. The remaining 30 to 40 per cent of the variation is not accounted for and represents an area for further study. Part of the unaccounted-for variation is a result of the variability of the froth measurements used.

From the multiple correlation technique the following observations were evident:

1. The ABS concentration in the mixed liquor filtrates was significantly correlated to the frothing parameters and accounted for more of the variation than any other single factor.

2. The organic nitrogen concentrations of the mixed liquor filtrates were not significantly correlated to the froth parameters. While this appears to be in contrast to the data obtained with the organic solution studies, it may be explained by the fact that the organic nitrogen is a gross measurement which does not differentiate the nitrogen-containing compounds believed to be associated with frothing.

3. The BOD concentration of the mixed liquor filtrates was not significantly correlated to frothing.

4. With regard to electrode potential measurements of the mixed liquors during aeration, a significant negative correlation was obtained, indicating that frothing, as measured by these parameters, is less with high values of electrode potential. This result appears to parallel reports that frothing is less in the advanced stages of nitrification.

5. For both pH and temperature of the mixed liquor samples, significant positive correlations were obtained for the persistency measurements, but not to the Σ values.

6. The ammonia-nitrogen concentrations of the mixed liquor filtrates was correlated to frothing both positively and negatively, depending on the inclusion and exclusion of certain data. The distribution of the concentrations encountered were not normal and did not lend themselves to statistical evalu-

ation. Further work is indicated in this area.

7. The suspended solids concentration of the mixed liquor was significantly correlated negatively to the froth parameter, persistency, when the statistical analyses were made on samples of mixed liquor from the same sewage treatment plant. This indicates that the froth parameters are lowered by increasing the suspended solids concentration.

In a simple correlation, the free ABS concentration was significantly correlated negatively to suspended solids concentrations, or in other words the free ABS concentration was lower for higher suspended solids concentrations. This is an important factor for subsequent studies on control measures for frothing of mixed liquors.

Continuing Study

The results to date have indicated that frothing in mixed liquors is the result of a number of factors. These must be considered in combination before an explanation can be made of the variations in frothing.

The project is being continued and various methods for the control of frothing are under study.

In order to do this, three continuous flow, bench scale activated sludge treatment plants operating in parallel have been developed. A general view of the apparatus is shown in Figure 8.

For a given substrate, measurements of frothing as well as solids, nitrogen, BOD, pH, ABS, surface tension, and others as needed, will be made in each cell of an aeration unit in order to relate frothing to these factors for dif-

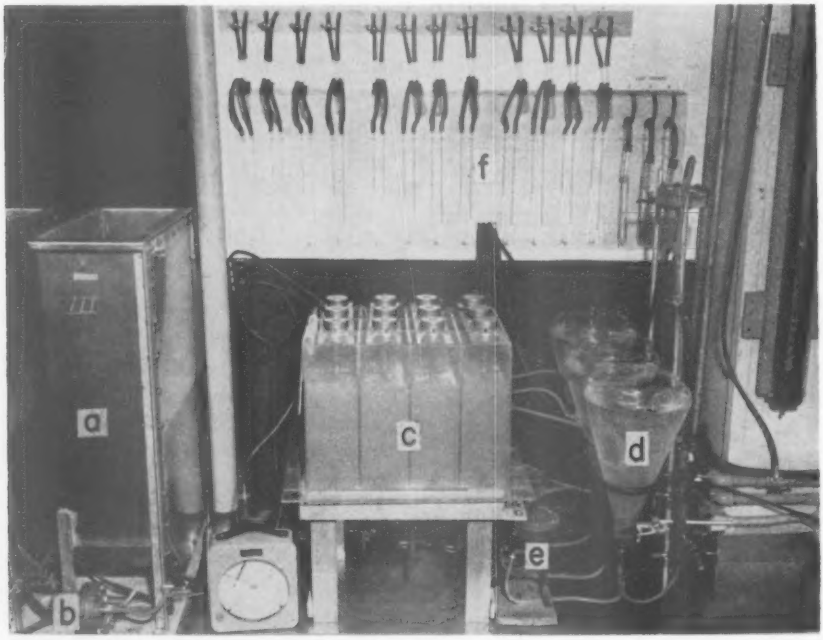

FIGURE 8.—General view of continuous flow laboratory activated sludge apparatus with parts as follows: (a) feed tanks, (b) feed pumps, (c) aeration cells, (d) settling tanks, (e) return sludge pumps, and (f) air supply manometers.

ferent aeration times. In addition, the substrate and aeration rates, can be varied in other runs. The suspended solids can be varied over a wide range with the existing facilities, and observations of the occurrence of frothing at low suspended solids concentrations with and without surface active agents can be made.

Acknowledgment

Grateful thanks are extended to the Association of American Soap and Glycerine Producers Inc. for their financial support of this research program. The assistance provided by the Numerical Analysis Laboratory of the University of Wisconsin is also gratefully acknowledged.

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TREATMENT PLANT DESIGN MANUAL ERRATA

Two corrections in the joint Federation—ASCE Manual of Practice, "Sewage Treatment Plant Design" have been brought to the attention of the Journal readers (THIS JOURNAL, **31**, 7, 818; July 1959). Those now using the manual are urged to notify either organization if other errors are found. With this information an errata sheet can be prepared and included in all manuals sold after its issuance. The same errata sheet would be available to those who made early purchases of the manual.

To be included in the errata sheet, all corrections must be received by either organization prior to November 1.

CORRECTION

In the 1958 Literature Review (THIS JOURNAL, **31**, 5, 501; May 1959) under the general subject of sewage, and specifically under the heading "Detergents," in the first column of page 533 the sentence beginning with "Subsequent passage through . . ." should end with the phrase, ". . . the detergent removed by the unit."

APPRAISING BASIN PERFORMANCE FROM DYE TEST RESULTS

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The "dye test" is a fairly standard method for revealing hydraulic detention characteristics of a sedimentation basin. A slug of dye or other marking substance is introduced into the feed to identify the fluid entering the basin at a particular moment. Overflow is subsequently sampled at timed intervals and the samples analyzed for dye. The resulting curve of dye concentration vs. time reveals the fraction of the marked slug of feed which is reaching the overflow after any given time of detention in the basin.

The function of a sedimentation basin, however, is to remove solids from suspension. No method has been developed for interpreting dye test results to indicate a quantitative index of the sedimentation efficiency. Qualitatively it usually is taken for granted that the longer it takes a dye front to arrive at the overflow, and the less the dispersion of the front, the more nearly perfect the basin. However, such qualitative interpretation does not suffice for the engineer. He is required to judge a basin ultimately, not on the basis of its hydraulic perfection, but on the basis of the over-all economy with which it performs its sedimentation function. In order to judge whether an improvement in dye test results is worth the over-all cost, he needs to know how much sedimentation results are improved.

Even the qualitative premise mentioned above is not necessarily valid in all cases. Removal of particles which do not flocculate during sedimentation, and which hence maintain a constant settling rate with respect to the suspending fluid, is governed by overflow rate and not at all by detention (1). Density current or vertically disposed short-circuiting does not decrease the removal of such particles. Because a dye test curve does not distinguish between density-current short-circuiting and either mixing or streaming, it follows that there may be no significant relationship between dispersion of the dye front and removal by sedimentation of non-flocculating particles. Consequently, in basins removing these particles the dye test curve is not by itself a direct indication of sedimentation performance.

Materials which coagulate or flocculate during sedimentation behave differently. It has been shown that for such materials detention may be a major factor in determining removals (2) (3) (4). In such a case the detention characteristics of a basin as revealed by a dye test are obviously significant and should be applicable as a measure of the removals to be expected. The problem is to express the dye test results as a "detention efficiency" which is related in some comprehensible and quantitative manner to the sedimentation results. This can be done, at least approximately, using an approach suggested by Camp (5). He states, "a rough estimate of the effect of short circuiting on removal may be had if it is assumed that the suspension is subjected to varying settling times, distributed as indicated by the dispersion curve."

Theory

The "detention efficiency" of a basin is defined here as its "effective" detention divided by its "nominal" detention. Effective detention is defined as the time it would take in a batch operation (under conditions otherwise identical) to produce a degree of flocculation equal to that obtained in the continuous basin. Nominal detention is the time required to pass, at the given feed rate, a volume equal to the volumetric capacity of the basin.

It is postulated that the removal effected in a basin will be a function of both basin overflow rate and degree of flocculation developed. If two basins are compared at identical overflow rates, then the comparative removals should be governed primarily by the amount of flocculation which is developed.

In order to use dye test results as a measure of effective detention, a relationship must be established between the range of detention times which characterize a basin, and the average or resultant degree of flocculation which would be attained in the blend of differently detained elements constituting the overflow from the basin. The degree of flocculation attained in any element of the flow depends not only upon detention time but also upon the characteristics of the flocculation reaction taking place. The results of averaging or blending the elements of flow having different detention times will depend on the relative effect of the different times on completeness of flocculation. Thus the nature and characteristics of the flocculation reaction must be known in order to deduce the effective detention.

Flocculation Rate

Camp (5) has deduced that the (relative) rate of flocculation should be directly proportional to the concentration. However, he defines the rate of flocculation as the number of particles reacting (contacting) per unit time per unit volume divided by the total number of unreacted particles present. That is,

$$\frac{\frac{dC}{dt}}{C} = KC \quad \ldots\ldots\ldots (1)$$

where

C = concentration of flocculable solids at time t,
t = time, and
K = the proportionality or rate constant.

According to the conventions of physical chemistry, Equation 1 would define a second order reaction, since

$$\frac{dC}{dt} = KC^2 \quad \ldots\ldots\ldots (2)$$

Integrating Equation 2 yields the following:

$$K(t - t_o) = \frac{1}{C} - \frac{1}{C_o} \quad \ldots\ldots (3)$$

where C_o and t_o are, respectively, the time and concentration at the start of the flocculation reaction.

Equation 3 has been confirmed experimentally in the laboratory on a substantial number of suspensions. Where the suspended material is homogeneous and flocculating in nature, a plot of $1/C$ vs. t as determined from batch tests is generally linear, showing that the reaction is indeed proceeding according to the postulated second order. The intercept of this linear plot with the $1/C$-axis when $t = 0$ can be taken as $1/C_o$ with C_o being the initial concentration of flocculable material present. This C_o will not always be identical to the measured initial concentration of suspended solids because there is normally a certain amount of relatively coarse, fast-settling material present in suspension which may not enter into the flocculation reaction.

In Figure 1 the values of the term $1/C - 1/C_o$ for a typical industrial waste have been plotted against time

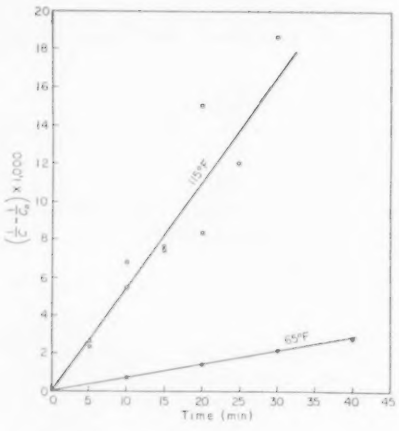

FIGURE 1.—Plot of $\frac{1}{C} - \frac{1}{C_o}$ vs. t for determining the rate of flocculation of an industrial waste.

and the slope of such a curve should equal the rate of flocculation.

However, the suspended solids in raw sewage are not homogeneous, but comprise three fractions; grit, flocculable solids, and non-flocculable colloids or non-removable solids. The concentration of non-removable solids is that which theoretically would remain in suspension at $t = \infty$. This may be determined by extrapolating a plot of C vs. $1/t$ to its intercept with the C-axis, where $1/t = 0$ and thus $t = \infty$ (Figure 2). The concentration of removable solids is the difference between total concentration C and C_∞. If the removable solids then flocculate at a second order rate, a plot of $\frac{1}{C - C_\infty} - \frac{1}{C_o - C_\infty}$ vs. t should be linear. Figure 3 shows this to be true within the limits of experimental error.

Detention Efficiency

The experimental evidence is that flocculation, in general, proceeds as a second order reaction. Detention efficiency can, therefore, be developed as follows:

The total dye introduced

$$= \int_{t=0}^{t=\infty} DFdt \ldots (4)$$

where

D = dye concentration,

F = constant flow rate, and

t = time.

The fraction of dyed slug of feed, f, arriving at overflow at time t is expressed below as:

$$f = \frac{DFdt}{\int_{t=0}^{t=\infty} DFdt} \ldots\ldots (5)$$

Unflocculated solids retained in element of overflow at time t from unit volume of dyed feed equal

$$\frac{DFdt\,C}{\int_{t=0}^{t=\infty} DFdt} \ldots\ldots (6)$$

Now from Equation 3,

$$C = \frac{1}{Kt + 1/C_o} \ldots\ldots (7)$$

If C_o is large with respect to C, the term $1/C_o$ can be neglected without introducing serious error in determing C.

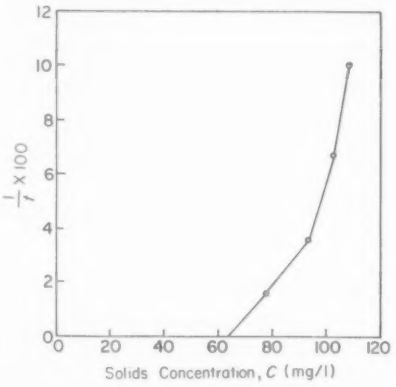

FIGURE 2.—Extrapolation plot for determining the concentration of non-removable suspended solids.

The resulting approximation is

$$C = \frac{1}{Kt} \quad \ldots\ldots\ldots\ldots (8)$$

After combining Equations 6 and 8, the unflocculated solids carried in the element of overflow at time t per unit volume of feed, may be shown to equal

$$\frac{\frac{Ddt}{Kt}}{\int_0^\infty Ddt} \quad \ldots\ldots\ldots\ldots (9)$$

The total unflocculated solids carried in all elements of overflow from a unit volume of feed then must be

$$\frac{\int_0^\infty \frac{Ddt}{Kt}}{\int_0^\infty Ddt} \quad \ldots\ldots\ldots\ldots (10)$$

and this must equal the concentration of unflocculated solids in a batch operation after the effective detention time. On the basis of the simplified Equation 8 above, this equals

$$\frac{1}{KS} \quad \ldots\ldots\ldots\ldots (11)$$

where S = effective detention time.

Therefore, combining Equations 10 and 11,

$$S = \frac{\int_0^\infty Ddt}{\int_0^\infty \frac{Ddt}{t}} \quad \ldots\ldots\ldots\ldots (12)$$

or approximately,

$$S = \frac{\sum_0^\infty \bar{D}\Delta t}{\sum_0^\infty \frac{\bar{D}\Delta t}{\bar{t}}} \quad \ldots\ldots\ldots\ldots (13)$$

where $\bar{D}$ is the average value of D over time increment Δt, and $\bar{t}$ is the average value of t over time increment Δt.

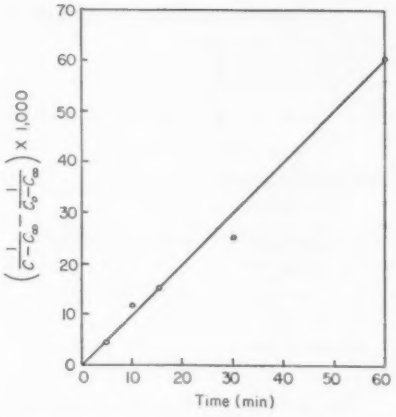

FIGURE 3.—Plot of $\frac{1}{C - C_\infty} - \frac{1}{C_o - C_\infty}$ vs. t for determining the rate of flocculation where non-removable suspended solids are present.

Expressed another way,

$$S = \frac{\sum_0^\infty (D - \tfrac{1}{2}\Delta D)\Delta t}{\sum_0^\infty \frac{(D - \tfrac{1}{2}\Delta D)\Delta t}{t - \tfrac{1}{2}\Delta t}} \quad \ldots (14)$$

Equation 14 is an extremely close approximation of Equation 12 when Δt is small enough so that the curve of $D = ft$ may be considered linear over the distance Δt. Because the effective detention as calculated from Equation 14 is valid only for second order flocculation reactions, and because the simplifying assumptions impose some further limitations on validity, this will be called the "standard detention." Dividing this by the nominal detention yields a detention efficiency figure here called the "standard" detention efficiency. This "standard" efficiency has proved to be a reasonable measure of the detention effectiveness of a clarification basin. In addition to the standard detention S, the average detention is also a useful figure, because it is a measure of the active volume of a basin, and hence permits determination of any unused or stagnant volume in the basin. The

average detention of dye is equal to

$$\frac{\int_0^\infty Dtdt}{\int_0^\infty Ddt} \quad \ldots\ldots\ldots (15)$$

or approximately

$$\frac{\sum_0^\infty (D - \frac{1}{2}\Delta D)(t - \frac{1}{2}\Delta t)\Delta t}{\sum_0^\infty (D - \frac{1}{2}\Delta D)\Delta t} \quad \ldots (16)$$

Procedure

The dye test yields a series of points showing dye concentration as a function of elapsed time. Ordinarily this curve should be plotted, although if the points are close enough together so that the curve may be treated as linear between adjacent points, the plot is not absolutely necessary. The first step is preparation of a table using the general column headings shown in Table I.

In the first column of Table I list the elapsed time, t, at which successive samples were taken, and in the third column the corresponding dye concentration, D. In case samples were taken too far apart to warrant treating the curve of dye concentration vs. time as linear between adjacent points, insert in the table as necessary, addi-

TABLE I.—Example of Standard Detention Computations

t, time (min)	Δt, time increment (min)	D, dye conc. (mg/l)	ΔD, dye conc. increment, (mg/l)	Y-function, $(D-\frac{1}{2}\Delta D)\Delta t$	Z-function, $\frac{Y}{t-\frac{1}{2}\Delta t}$	W-function, $(t-\frac{1}{2}\Delta t)Y$
6	—	0.00	—	—	—	—
7	1	0.01	0.01	0.01	0.002	0.06
8	1	0.07	0.06	0.04	0.005	0.30
9	1	0.27	0.20	0.17	0.020	1.45
10	1	0.72	0.45	0.49	0.051	4.66
11	1	1.03	0.31	0.87	0.083	9.14
12	1	1.12	0.09	1.07	0.093	12.31
13	1	1.25	0.13	1.18	0.094	14.75
14	1	1.07	−0.18	1.16	0.086	15.66
15	1	0.96	−0.11	1.02	0.070	14.79
16	1	0.88	−0.08	0.92	0.059	14.26
17	1	0.81	−0.07	0.85	0.052	14.03
18	1	0.81	0.00	0.81	0.046	14.18
19	1	0.80	−0.01	0.81	0.044	14.99
20	1	0.79	−0.01	0.80	0.041	15.60
21	1	0.78	−0.01	0.79	0.039	16.20
22	1	0.76	−0.02	0.77	0.036	16.56
23	1	0.75	−0.01	0.76	0.034	17.10
24	1	0.67	−0.08	0.71	0.030	16.69
26	2	0.57	−0.10	1.24	0.050	31.00
28	2	0.55	−0.02	1.12	0.041	30.24
30	2	0.52	−0.03	1.08	0.037	31.32
32	2	0.48	−0.04	1.00	0.032	31.00
34	2	0.45	−0.03	0.94	0.028	31.02
36	2	0.43	−0.02	0.88	0.025	30.80
38	2	0.39	−0.04	0.82	0.022	30.34
40	2	0.35	−0.04	0.74	0.019	28.86
45	5	0.30	−0.05	1.65	0.039	70.13
50	5	0.19	−0.11	1.25	0.026	59.38
55	5	0.11	−0.08	0.75	0.014	39.38
60	5	0.07	−0.04	0.45	0.008	25.87
70	10	0.03	−0.04	0.50	0.008	32.50
80	10	0.02	−0.01	0.30	0.004	22.50
90	10	0.00	−0.02	0.10	0.001	8.50
—	—	—	—	$\Sigma Y = 26.05$	$\Sigma Z = 1.239$	$\Sigma W = 715.57$

tional values determined from the plot. Values should be tabulated until the dye concentration has fallen to zero, or below limits of detection. Any units of time and dye concentration may be used.

In the second column list the increment of time, Δt, between the value in question and the preceding value.

In the fourth column list the increment of dye concentration, ΔD, between the value in question and the preceding value. Note that when the dye concentration is falling, ΔD will be negative.

In the fifth column list calculated values of the Y-function, $(D - \frac{1}{2}\Delta D)\Delta t$.

In the sixth column list calculated values of the Z-function, $\frac{Y}{(t - \frac{1}{2}\Delta t)}$.

In the seventh column list calculated values of the W-function, $Y(t - \frac{1}{2}\Delta t)$.

Pertinent relationships are as follows:

1. Standard detention $= S = \dfrac{\sum Y}{\sum Z}$
2. Average detention $= \dfrac{\sum W}{\sum Y}$
3. Nominal detention $= \dfrac{\text{Volume}}{\text{Flow}}$
4. Standard detention efficiency
$$= \frac{\text{Standard detention}}{\text{Nominal detention}}$$
5. Fraction dead volume in tank
$$= \frac{\text{(Nominal detention)—(Average detention)}}{\text{(Nominal detention)}}$$

Where detention is required in a clarification basin, the standard detention efficiency as here calculated from a dye test has been found to be a reasonable and functional measure of the effectiveness of the basin.

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SANITARY CHEMIST NEEDED

The City of Springfield, Mo., has announced the need for a Sanitary Chemist in the sewage treatment program. The individual should be qualified through training and experience to perform responsible duties in charge of a sewage treatment plant laboratory, in which control procedures are maintained for a plant treating 15 mgd. Duties involve laboratory analyses of sewage and industrial wastes, including cyanides and heavy metals.

Application stating minimum starting salary acceptable should be made to the Personnel Department, City Hall, Springfield, Mo.

CHLORINE DETERMINATIONS IN WASTEWATERS

By S. Katz and H. Heukelekian

Department of Sanitation, Rutgers University, New Brunswick, N. J.

I. EVALUATION OF THE CYANOGEN CHLORIDE METHOD

The authors reported on these investigations in two parts, the first at the 132nd National Meeting of the American Chemical Society in New York, September 8–13, 1957; and the second at the 134th National Meeting of the same organization in Chicago, September 7–12, 1958. They appear together because of the natural continuity of subject.

Both investigations were prepared as Papers of the Journal Series, New Jersey Agricultural Experiment Station, Rutgers University, New Brunswick, N. J.

Determinations of residual chlorine by the orthotolidine, starch-iodide, and amperometric methods (1) have the common disadvantage of not being specific for chlorine, nor even for the halogens, as they are dependent on the oxidation potential of the materials present.

The cyanogen chloride method (2) (3) (4) (5) (6) (7) (8) offers a way to circumvent this disadvantage. The method involves a reaction between halogen and cyanide to produce cyanogen halide, which when reacted with a pyridine-benzidine mixture gives a yellow-orange color (7) (8) proportional to the concentration of halogen in the sample. The reaction is specific for free halogen and compounds containing available halogen. The formation of the color complex is not affected by the ORP of the waste, and extraction of the color complex with 1-butanol eliminates the interference of color and turbidity. As chlorine is the most commonly used halogen for disinfection, with bromine and iodine rarely used, this method can be considered specific for chlorine and chlorine compounds.

Materials and Methods

Apparatus

1. Spectrophotometer for use at 480 mμ.
2. Centrifuge.
3. Pipetting bulb.

Reagents (C.P. or analytical reagent grade)

1. Orthophosphoric acid solution, 10 per cent.
2. Pyridine solution containing 25 per cent by volume water-white pyridine, 2 per cent concentrated HCl, and 73 per cent distilled water.
3. Benzidine dihydrochloride, 2 per cent in 0.12 N HCl.
4. Mixed reagent (prepared just before use) containing 50 ml of the pyridine solution and 3 ml of the benzidine dihydrochloride solution.
5. 1-butanol.
6. Sodium arsenite solution, 2 per cent.
7. CN solution made up by weighing carefully dried and assayed NaCN or KCN, 1,000 mg/l CN.
8. Saturated bromine or chlorine water.

Procedure

The procedure used for the determination of residual chlorine in wastes is as follows:

Pipet a 10-ml aliquot of the sample to be measured into a ¾- × 6-in. screw-top test tube and add 2 drops of the 10 per cent orthophosphoric acid solution. Add 1 ml of the 1,000 mg/l cyanide solution and shake. Add 10 ml of 1-butanol and shake again. Add 5.3 ml of the mixed pyridine-benzidine reagent, and shake well for 15 sec. Allow 10 min for the development of the yellow-orange color. Centrifuge for one minute to remove turbidity and any emulsion that might result with some wastes. Remove the butanol layer with the aid of the pipetting bulb and measure on the spectrophotometer 480 mμ and compare with the standard calibration curve.

To establish a calibration curve the procedure is slightly altered. Pipet 10 ml of dilute cyanide standards, corresponding to the range of 0.05 to 1.09 mg/l chlorine, into a ¾- × 6-in. screw-top test tube. Add 2 drops of the 10 per cent ortho-phosphoric acid solution followed by 3 drops of saturated bromine, and shake. Discharge the excess bromine by the dropwise addition of the 2 per cent sodium arsenite, until the yellow color of the bromine is discharged with one drop in excess. Extract the resulting cyanogen chloride or bromide by shaking with 1-butanol. Then follow the procedure for the determination of the residual in wastes.

Blanks should be determined at all times when working with wastes.

Results

Establishment of Calibration Curves

The preparation of calibration curves using chlorine standards in water necessitates the use of glassware and water which are free of chlorine demand, and requires extreme care. In order to justify the use of cyanide standards, initially both cyanide and chlorine standards were used and compared. It was found that either chlorine or cyanide standards can be used equally well, and that for general all-around ease and simplicity, cyanide standards are to be preferred. This is particularly true when working with wastes where chlorine standards cannot be used.

The use of bromine instead of chlorine in establishing calibration curves is justified by the fact that both give the same curve. Bromine has the advantage of color which can be discharged with a minimum of arsenite, thus eliminating large variations in the size of the sample.

Stability

The yellow-orange color which is developed is stable from 10 to 45 min beyond which changes in intensity make the color variable. However, the cyanogen chloride formed in the reaction and extracted in 1-butanol from either water or sewage is stable for 24 to 48 hr. This stability insures that an analysis need not be finished in the field but can be brought back to the laboratory.

Range

The method as described measures from 0.05 to 1.09 mg/l chlorine directly. As it is often necessary to measure quantities greater than 1.09 mg/l, there are two general methods which can be used successfully. The first is the establishment of calibration curves using larger amounts of solvent, such as 25, 50, or even 100 ml of extracting solvent, depending on the range desired. The second is by dilution of the sample with chlorine demand-free water to where it is in the range of an established calibration curve, and then multiplying the values found by the suitable dilution factor. Both these methods were tried and found to be satisfactory.

pH

The cyanogen chloride method is not affected within a pH range of 1.0 to 8.5. Above a pH of 8.5 the cyanide ion is readily oxidized to cyanate in the presence of chlorine. As cyanate does not react with halogens to form cyanogen halides the pH of the sample must be adjusted to below 8.5 for the analysis.

Temperature

Temperature has no effect on the method in the range of 5 to 30°C. Above 30°C and with increasing temperatures upward, the variations are due to the increased solubility of the 1-butanol in water. Wherever necessary samples should be cooled below 30°C before analysis.

Interferences

Several ions were tested for possible interference with the cyanogen chloride method. The following ions showed no effect on the determination: (a) NO_3 at 50 mg/l, (b) NO_2 at 50 mg/l, (c) Fe^{+3} at 100 mg/l, (d) Mn^{+2} at 50 mg/l, (e) chlorinated Mn^{+2} at 50 mg/l, (f) SO_4 at 5,000 mg/l, and (g) excess cyanide at 50 mg/l. The concentrations were not the maximum limits as these were not determined, but generally these concentrations are far in excess of those found in wastes.

The presence of cyanide or thiocyanate in the waste constitutes an interference as both these ions form cyanogen chloride on chlorination. However, in none of the wastes studied has this caused any interference that could not be compensated for on the spectrophotometers by means of a baseline technique. Some amino acids also form cyanogen chloride on chlorination but again any color formed can be compensated for by means of the blank.

Standard Calibration Curve

The development of a standard calibration curve for a Beckman DU Spectrophotometer involved 16 independent replications using cyanide standards and converting to chlorine values by means of a factor of 2.73. Table I shows a summary of these results.

As can be seen from Table I there is a relative error of 1 to 6 per cent with the greatest error existing at the lowest concentrations. The error of 6 per cent is generally out of line with the other values and this is attributed to the fact that absorbance readings are close to 0.100. This generally is the case when values are used that are below 0.100 or greater than 1.1 absorbancy units. The relative error is much greater and can be attributed to instrumental causes rather than causes inherent in the method itself.

The calibration curve for the Beckman DU Spectrophotometer was compared with those of a Bausch and Lomb

TABLE I.—Data for Standard Calibration Curve of Residual Chlorine by the Cyanogen Chloride Method Using a Beckman DU Spectrophotometer

Chlorine (mg/l)	Absorbance					
	Max	Min	Avg	Mean Deviation	Std. Deviation	Relative Mean Deviation (%)
0.05	0.085	0.063	0.076	0.004	0.005	5.3
0.11	0.146	0.124	0.135	0.007	0.008	5.2
0.27	0.306	0.277	0.290	0.003	0.004	1.1
0.54	0.557	0.463	0.529	0.019	0.023	3.6
0.82	0.830	0.741	0.799	0.023	0.028	3.5
1.09	1.056	0.979	1.042	0.020	0.024	1.9

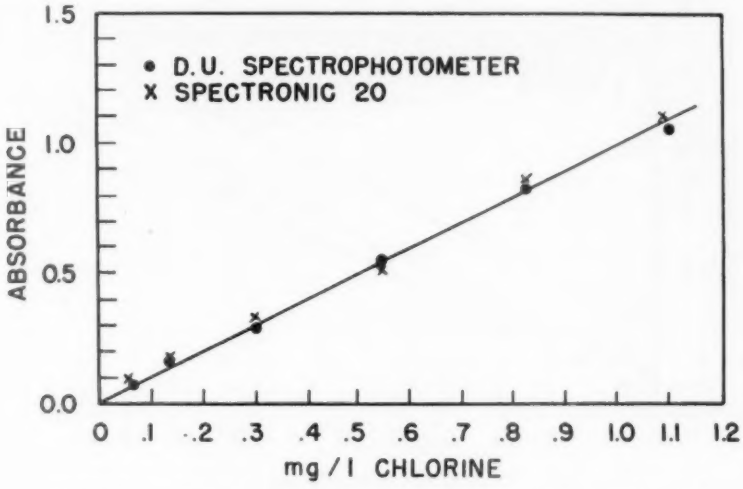

FIGURE 1.—Standard calibration curve for DU Spectrophotometer and Spectronic 20.

Spectronic 20 and found to agree quite well. Figure 1 shows the DU standard calibration curve and the Spectronic 20 values. This is advantageous in that instruments such as the DU would not be available as a general rule in treatment plant laboratories while an instrument such as the Spectronic 20 would more likely be available in such plants.

Comparison with Other Existing Methods in Water

The orthotolidine, amperometric, and cyanogen chloride methods were compared in New Brunswick, N. J., tap water. In Table II are shown the results of three independent determinations. As could be expected, the methods compared quite well. The starch-iodide titration was not included as it had been used previously to justify the use of cyanide standards instead of chlorine standards.

Establishment of Calibration Curves in Wastes

Calibration curves were established in different wastewaters varying from domestic sewage to municipal and industrial wastes. A parallel relationship between the water calibration curve and those of the wastewaters is noted. By means of a baseline technique, setting the transmittance or absorbance of the waste to that of the water blank, the waste curve falls on the water curve. Figure 2 shows the parallel relationship between three wastewaters and the water curve.

Comparison with Other Existing Methods in Wastes

In comparing the methods for the measurement of residual chlorine in

TABLE II.—Comparison of Various Methods for Determining Residual Chlorine in Water

Method	Residual Chlorine (mg/l)		
	Trial 1	Trial 2	Trial 3
Amperometric	0.17	0.43	0.37
Cyanogen chloride	0.18	0.42	0.32
Orthotolidine	0.15–0.20	0.4	0.3–0.4
Starch-iodide*	—	—	—

* Starch-iodide titration was used to justify use of cyanide standards in the establishment of the standard calibration curve.

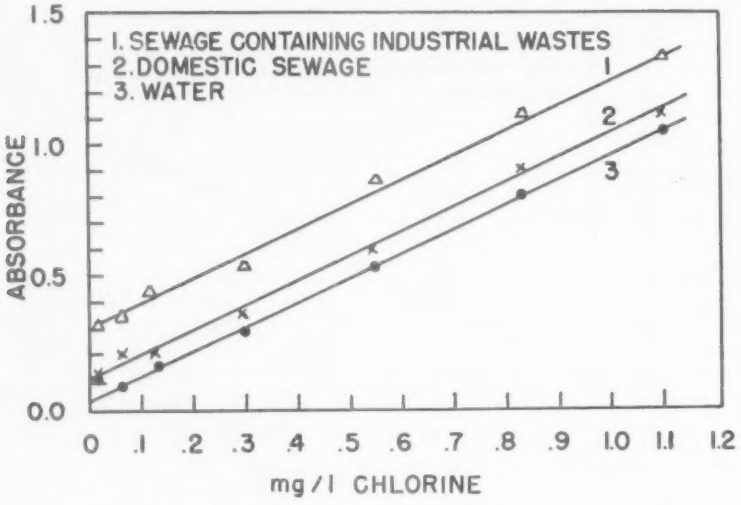

FIGURE 2.—Calibration curves for two types of wastes and water.

wastes, the orthotolidine and starch-iodide methods were not included because these methods cannot be used in wastes which contain turbidity and color. In the following study the amperometric and cyanogen chloride methods were compared. As can be seen in Table III there is no constant relationship existing between the amperometric and cyanogen chloride methods. This is also an indication that both methods do not measure the same type of chlorine nor even a constant per cent of one or the other.

Discussion

The orthotolidine, amperometric, starch-iodide, and cyanogen chloride methods compare quite well in water. However, when the methods are compared in some industrial wastes, the orthotolidine and starch-iodide methods were of no value because of color and turbidity interference. Neither color nor turbidity affected the amperometric or the cyanogen chlorine method.

It is evident that the amperometric and cyanogen chloride methods do not measure the same type of chlorine nor even a constant percentage of one or the other. However, this does not mean that one method is distinctly better than the other, as evidence for that is lacking. The amperometric method fails in some industrial wastes where residuals are indicated before chlorine is added, or where there are substances that coat or poison the electrode. The cyanogen chloride method is not as sensitive to small quantities of chlorine as is the amperometric. Like the amperometric method the cyanogen chloride method is not affected by the color of the waste. The butanol does not extract appreciable color from any of the wastes and what color is extracted is easily compensated for in the blank.

In water, the cyanogen chloride method does not distinguish between types of chlorine while the amperometric does. In wastes neither method distinguishes chlorine types. As a measure of total chlorine does not necessarily measure the disinfecting power, the correlation between num-

TABLE III.—Comparison of Amperometric and Cyanogen Chloride Residuals in Wastes

Waste Source	Amp. Residual (mg/l)	CNCl Residual (mg/l)	Amp./CNCl Ratio
Domestic sewages	0.05	0.48	0.11
	0.10	0.35	0.28
	0.15	0.30	0.50
	0.40	0.25	1.60
	0.59	0.27	2.18
	0.75	0.71	1.05
	0.80	0.63	1.26
	1.35	1.20	1.10
	1.78	0.82	2.17
	1.80	1.77	1.02
	2.15	1.67	1.29
	2.20	1.15	1.92
Trickling filter effluent	0.25	0.73	0.34
	0.75	1.05	0.71
	0.90	0.51	1.77
	1.12	0.21	5.4
	1.20	1.06	1.14
Yeast manufacturing wastes	0.59	0.82	0.72
	2.75	0.48	3.92
Cigarette paper manufacturing wastes	0.45	0.17	3.28
	0.72	0.18	3.05
	1.05	0.28	4.24
Municipal sewage and industrial wastes	1.00	1.67	0.59
	1.00	0.39	2.58
	1.20	0.32	0.39
	1.55	0.24	6.45
	1.55	1.67	0.93
	3.00	1.10	1.82
Dye manufacturing wastes	0.45	0.27	1.66
	0.65	0.29	2.24
	0.85	0.95	0.90
	1.40	0.25	5.60
	1.49	0.38	0.39
	1.50	1.16	1.29
	1.74	0.84	2.07
	2.01	0.64	3.15

bers of coliform organisms remaining and chlorine residual is the final criterion of the superiority of one method over the other. This aspect is reported in the second phase of this study.

In industrial wastes where there is color or turbidity, the cyanogen chloride method is superior to the orthotolidine and starch-iodide, as these factors do not affect the cyanogen chloride method.

Summary and Conclusions

The cyanogen chloride method for the analysis of residual chlorine in water and wastes offers a procedure which is subject to little interference. The range of the method without dilution of solvent or sample is 0.05 to 1.09 mg/l. A wide variance exists between the cyanogen chloride and amperometric methods, but the superiority of one method over the other has not been demonstrated. The cyanogen chloride method is superior to both the orthotolidine and starch-iodide methods in the wastes tried, but in water all four methods give comparable results.

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II. CORRELATION BETWEEN NUMBERS OF COLIFORM ORGANISMS REMAINING AND CYANOGEN CHLORIDE AND AMPEROMETRIC RESIDUALS IN WASTES

The final criterion for an analytical method for the determination of residual chlorine in wastes is the manner in which the results agree with the numbers of coliform organisms remaining. If the correlation between the coliform organisms remaining and the chemically determinable residual is good, the results of a given analytical method can be used as an index of disinfection and for reliable control of effluent chlorination.

Day, Horchler, and Marks (9) compared the orthotolidine and amperometric methods with respect to correlating numbers of coliforms remaining with residual chlorine concentrations in three types of domestic wastes. The orthotolidine and amperometric methods accounted for 79 and 83 per cent of the variation in numbers of coliforms remaining in trickling filter effluent, respectively. In settled sewage and chemical treatment effluent, the amperometric method accounted for 65 and 80 per cent of the variation in coliforms remaining while the orthotolidine method accounted for 32 and 37 per cent. The amperometric method gave significantly better correlation in settled sewage and chemical treatment effluent.

Heukelekian, Day, and Manganelli (10) compared the orthotolidine, starch-iodide, and amperometric methods for the purpose of determining the best chemical yardstick of disinfection. The orthotolidine method accounted for 21.7 to 53.3 per cent; the starch-iodide method accounted for 14.9 to 53.3 per cent; and the amperometric method accounted for 25.6 to 47.6 per cent of the variation in the numbers of coliforms remaining in the wastes studied. No definite statistical superiority of one method of determining residual chlorine over another with respect to correlating numbers of organisms remaining in the chlorinated effluents was found. The MPN method of enumerating coliforms was much less sensitive and subject to greater variations than the chemical determinations used.

Methods and Procedures

The cyanogen chloride method for determining residual chlorine as outlined in Part I and the amperometric method (1) were compared in the following wastes:

1. Domestic sewage from a municipal plant (primary effluent).
2. Domestic sewage from an institutional plant (primary effluent).
3. Trickling filter effluent from a domestic plant.
4. Sewage containing a high proportion of industrial wastes.

The results were compared statistically with the numbers of coliforms remaining to determine which method was the best chemical yardstick of disinfection.

The wastes were adjusted to a pH range of 6.5 to 7.5 and temperature of $20° \pm 2°C$ whenever necessary.

Each sample of waste was prepared for the study by filtering through glass wool to remove the larger suspended solids. Varying volumes of standardized chlorine water were added to 500-ml portions of the prepared waste. The chlorinated wastes were stirred periodically during the 30-min contact interval. Residual chlorine was determined by the amperometric and cyanogen chloride methods at the end of the contact period. Approximately 75 ml of the chlorinated sewage were added to a sterile test tube containing 1 ml of 2-per cent sodium sulfite, to discharge the residual chlorine.

Dilutions of 1 : 10 and 1 : 100 were made. One milliliter of these dilutions as well as 1 ml and 10 ml of the dechlorinated waste were placed in 75 ml of modified dilution water, and passed through the membrane filter. The coliform organisms were enriched for 2 hr on M-Enrichment media and transferred to modified Endo media for 18 to 22 hr at 37°C (1). Colonies having the characteristic metallic sheen were counted with the aid of a microscope. Five to 85 colonies per cellulose acetate pad were counted. The results were expressed as numbers of coliforms remaining.

The procedure for the combined sewage and industrial wastes was identical to that used for the other three wastes with the exception of the method for the enumeration of organisms. Coliform determinations were made by planting five portions of a number of dilutions serially into lactose broth tubes. The positive presumptives were confirmed after 48 hr at 37°C in brilliant green bile. The results were expressed as the most probable number on the basis of brilliant green positive tubes after an additional 48 hr incubation at 37°C.

TABLE IV.—Statistical Correlation of the Amperometric and Cyanogen Chloride Methods with Coliform Organisms Remaining in Wastes

Method	r^2	r	Z	X
(*a*) Domestic Sewage from Municipal Plant				
Cyanogen chloride	0.690	0.831	1.191	0.758
Amperometric	0.577	0.761	1.096	
(*b*) Domestic Sewage from Institutional Plant				
Cyanogen chloride	0.772	0.879	1.370	0.343
Amperometric	0.722	0.850	1.255	
(*c*) Trickling Filter Effluent				
Cyanogen chloride	0.748	0.865	1.203	0.652
Amperometric	0.599	0.744	1.030	
(*d*) Sewage Containing Industrial Wastes				
Cyanogen chloride	0.178	0.422	0.450	1.532
Amperometric	0.453	0.673	0.817	

This procedure was repeated 10 different times with 10 separate samples of each waste.

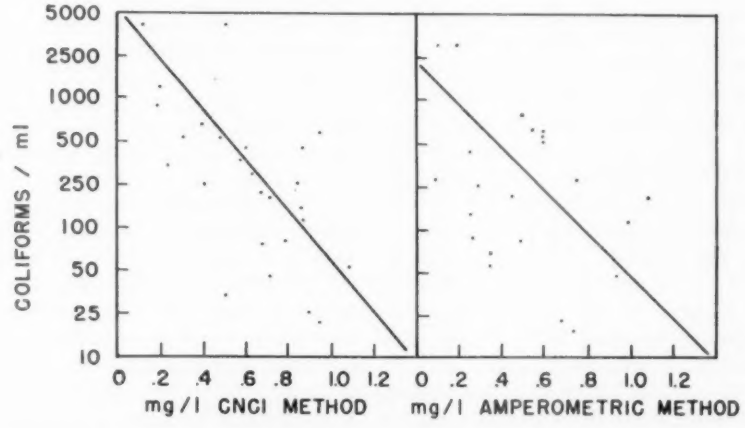

FIGURE 3.—Correlation of chlorine residuals with coliform organisms remaining in domestic municipal waste.

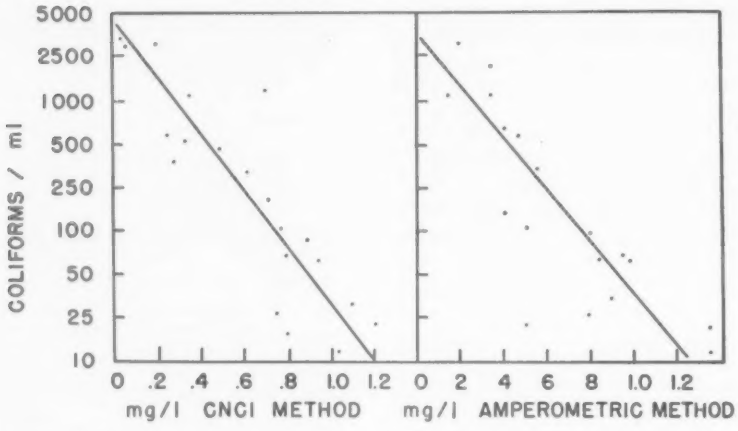

FIGURE 4.—Correlation of chlorine residuals with coliform organisms remaining in institutional waste.

Results

Domestic Sewage No. 1

The results of the 10 replications are presented in Figure 3 where the numbers of coliforms remaining are plotted against residual chlorine concentrations measured by the amperometric and cyanogen chloride methods. The plots of the results show a wide scatter. The line drawn is the calculated line of best fit (11) as determined by the least square of the coefficient of correlation, summary of the correlation data. The coefficient of determination, r^2, is the squares method. Table IV presents the r, and is a direct measure of the per cent of variation in the numbers of coliforms remaining caused by the change in residual chlorine. Z (11) is obtained by transforming r to a normal distribution. The calculated X value (5), if greater than 3, indicates the superiority of one method over another on the basis of the 95 per cent confidence limits.

The residual chlorine concentration as determined by the cyanogen chloride method accounted for 69.0 per cent of the variation in coliform numbers. The amperometrically determined residuals accounted for 57.7 per cent of the coliform variation. The calculated X value of 0.758 indicates no statistical difference between the cyanogen chloride and amperometric methods on the basis of 95 per cent confidence limits.

Domestic Sewage No. 2 (Institutional Plant)

Figure 4 shows the results of 10 replications of a second domestic sewage where the numbers of coliform organisms are plotted against the amperometric and cyanogen chloride residual chlorine concentrations. As was noted with the previous domestic sewage results, the points show appreciable scatter about the calculated line of best fit. The residual chlorine concentrations as determined by the cyanogen chloride method account for 77.2 per cent of the variation in coliform numbers remaining, while the amperometrically determined residuals account for 72.2 per cent of the variation in coliform numbers (Table IV). The calculated X value of 0.343 shows no significant difference at the 95 per cent confidence limits.

Trickling Filter Effluent

Figure 5 shows the results of 10 replications of the chlorination study on trickling filter effluent. The numbers of coliform organisms remaining, as enumerated by the membrane filter procedure, are shown versus the chlorine residuals determined by the cyanogen chloride and amperometric methods. The points are widely distributed about the calculated line of best fit. The cyanogen chloride method accounts for 74.8 per cent of the variation in the coliform numbers remaining, while 59.9 per cent of the variation is caused by the amperometrically determined residuals. The calculated X value of 0.642 (Table IV), indicates no statistical difference between the results obtained by either method.

Combined Sewage and Industrial Wastes

The membrane filter method could not be used for the comparison of the results of the amperometric and cyanogen chloride methods with the numbers of coliforms remaining in the sewage containing a high proportion of industrial wastes. Results of preliminary studies indicated that some inhibitory agent may have been retained on the cellulose acetate filter causing interference with the enumeration of coliforms. It was, therefore, necessary to revert to the multiple tube MPN.

The results of 10 separate samples with this waste are presented in Figure 6 where the residuals measured by the amperometric and cyanogen chloride methods are shown versus the MPN of coliforms remaining.

Only 17.8 per cent of the variation in the MPN can be accounted for by the cyanogen chloride residuals. The amperometrically determined residuals account for 45.3 per cent of the variation in coliform numbers (MPN). The calculated X value of 1.58 (Table IV) indicated no definite statistical superiority of one method over another as a chemical index of disinfection.

Discussion

The final criterion for a residual chlorine method is the manner in which it correlates with disinfection. Residual chlorine concentrations determined by the cyanogen chloride method were not superior to amperometrically determined residuals as a chemical index of disinfection. Although the results obtained by the cyanogen chloride

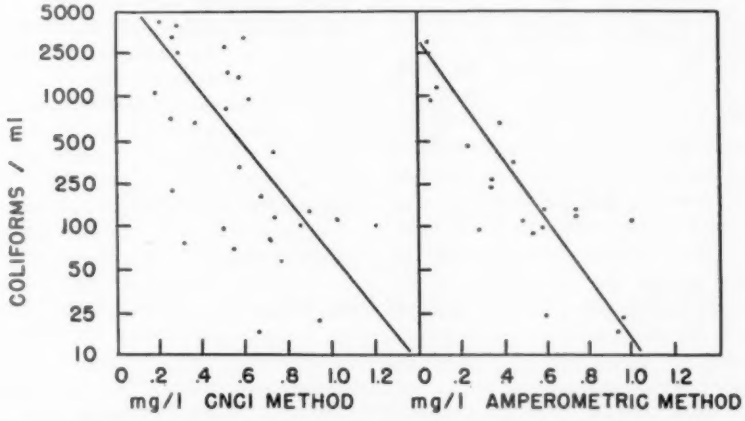

FIGURE 5.—Correlation of chlorine residuals with coliform organisms remaining in trickling filter effluent.

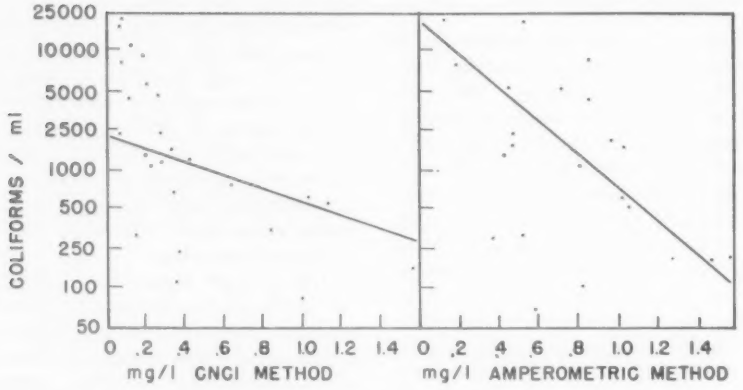

FIGURE 6.—Correlation of chlorine residuals with coliform organisms remaining in sewage containing industrial wastes.

method possessed a higher coefficient of determination than the amperometric results in two primary and one secondary effluent, this difference was not statistically significant. In sewage containing a high proportion of industrial wastes, the results obtained by the amperometric method yielded a higher coefficient of determination with the MPN than the cyanogen chloride method. This difference also did not prove to be statistically significant.

The results indicate little definite superiority of one method of determining residual chlorine over another as a chemical index of disinfection.

Only 60 to 80 per cent of the variation in coliform numbers was caused by the increase in the concentration of the residual chlorine as determined by either method. The 20 to 40 per cent of the unaccounted-for variation may be caused by imperfections in the membrane filter method, by the media, by mixing during the preparation of the dilutions, and by variations in composition of the waste samples, or by a combination of these factors. It is believed that the coliform test is less sensitive and subject to greater errors than the chemical determinations for residual chlorine.

The failure of the membrane filter method of coliform enumeration in wastes containing high concentrations of industrial wastes shows that this method has definite limitations. This in no way detracts from the fact that whenever applicable the membrane filter method of coliform assay yields the best precision of any method used at present.

Summary and Conclusions

The cyanogen chloride and amperometric methods were compared with the numbers of coliform organisms remaining in two primary effluents, a secondary treatment effluent, and a sewage containing industrial wastes, in order to determine the better chemical index of disinfection. Although the results obtained by the cyanogen chloride method exhibited higher coefficients of determination in the two primary effluents and the secondary effluent, there was no statistical significance to this difference. In the sewage containing a high proportion of industrial wastes, the results obtained by the amperometric method yielded a higher coefficient of determination than that obtained for the cyanogen chloride method. However, this difference also

was not statistically significant. There is no statistically significant difference between both methods as indexes of disinfection in the wastes studied. Both methods will yield equivalent results for the chemical control of effluent chlorination.

Acknowledgment

This study was supported by a grant from the United States Public Health Service, Division of Research Grants.

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OCTOBER IS THE TIME

(Oct. 12-15, 1959)

DALLAS IS THE PLACE

HEADQUARTERS AT
STATLER HILTON HOTEL

SESSIONS AND EXHIBITS AT
DALLAS MEMORIAL AUDITORIUM

THE TEXAS WATER AND SEWAGE WORKS ASSOCIATION IS THE HOST FOR THE

BIG

32ND ANNUAL MEETING

FEDERATION OF
SEWAGE AND INDUSTRIAL WASTES
ASSOCIATIONS

MAKE YOUR ROOM RESERVATION NOW

Industrial Wastes

INDUSTRY AND THE COMMUNITY INFORMATION PROGRAM *

By George A. Lloyd

Assistant Manager, Public Relations Department, Esso Standard Oil Company, New York, N. Y.

The theme for this conference—the Public Relations Aspects of Industrial Waste Treatment—is very timely. It is gratifying to see that a group of technical people recognize the need for keeping the public informed. It is not necessary to look very far to see the tremendous achievements science has brought about in keeping the Pennsylvania air and water cleaner and more healthful. As the years go by, it appears that predictions can be made with confidence that more and more innovations will be developed to continue the progress already made. But during this period it is necessary to tell the story. To do this it is necessary to put some thought into an area not governed by technology. When thought is given to "Public Relations Aspects," the problem that is basic to any society—the problem of communication—is at hand.

This discussion of communication is directed to something all in this meeting have in common—industrial waste treatment. But there is agreement among those with primary interest in the technical aspects of the problem and those with public relations interests that technical progress alone is not enough. The story of that progress must be told effectively. The job of a public relations department in an industrial organization is to tell the story of what is being done to combat air and water pollution. The audience is made up of the company's employees and, equally important, neighbors and friends who make up the surrounding communities.

It has been said that if a tree falls out in the forest with no one around, it makes no noise. Much the same principle applies to pollution. An industrial plant out in the wilderness produces no smell, no smoke, no foul water. It takes a nose and a pair of eyes to translate these ordinary by-products of industry into offensive problems.

But an industrial plant cannot be operated without people. And as soon as people are present, so are problems —public relations problems. As letters of complaint and telephone calls pour in, the plant manager becomes a public relations man whether he likes it or not. It soon becomes obvious that the pollution problem is a real public relations problem.

It has been said that there can be good public relations or bad public relations, but there can't be "no public relations." This means that there will be either good communication or poor communication with the people who are affected. Public awareness of what the organization is doing to combat pollution doesn't just happen—it

* Presented at the 7th Annual Pennsylvania Clean Streams Conference, Reading, Pa., Apr. 24, 1959.

takes a lot of hard, thoughtful, serious work.

To be more specific, the balance of this paper will deal with the petroleum industry in general and one company in particular. Even though all the answers are far from being at hand, it is hoped that by describing what has been done by one company and emphasizing where there has been particular success, that others may find some seeds that will flower in other organizations.

Those in the petroleum industry have long felt the effects of being singled out for special attention. You can't hide a refinery. It's too big. It operates at night as well as in the day. The strange lights, the peculiar smells, and the mystery that goes on inside a refinery make it particularly vulnerable to the frowns of the community.

In order to simplify the steps Esso Standard Oil Company has taken, the communication program is arbitrarily split into two parts: the shotgun and the rifle. In actual practice, these two approaches overlap to some extent, but considering them in this way may be helpful.

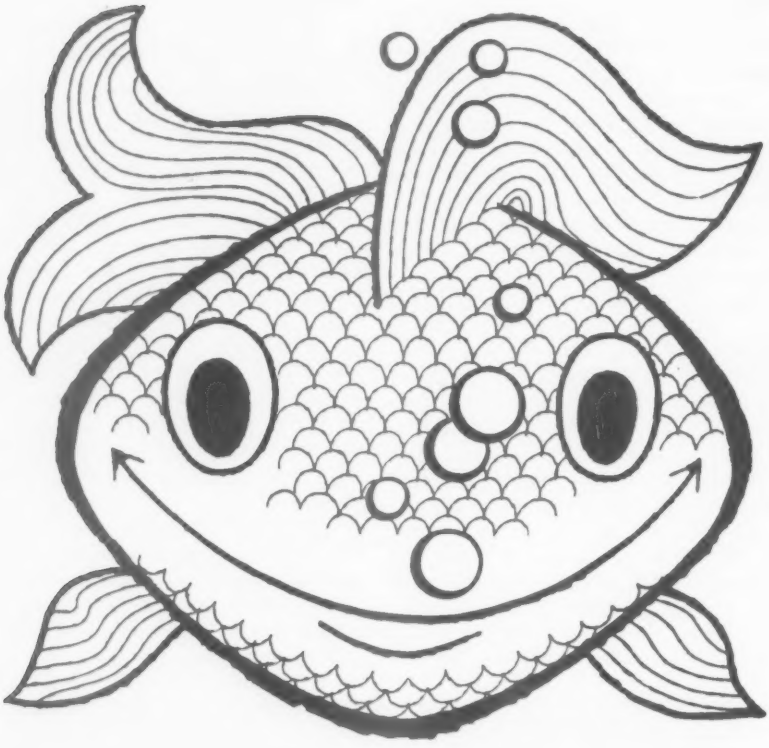
Shotgun Approach

The shotgun, or general approach, makes the widest possible use of the written media of communications: the press, booklets and pamphlets, and institutional advertising.

Certainly, working closely with the press is no new concept. This company, as many others, constantly works on extending and improving its contacts with the newspapers and magazines which can tell the story to the widest possible audience. Releases are distributed on new equipment, improvements, and figures showing the amount spent on pollution control to local newspapers and national press services.

Continual efforts are made to know the members of the press. One method has been to conduct special press trips through refineries and to show the measures that have been adopted to combat pollution.

FIGURE 1.—Examples of publications used for general distribution.



KEEPING THE SMILE ON A GOLDFISH

Esso Standard Oil Company likes healthy, happy goldfish. And we know that *our* goldfish are as healthy and happy as any around.

We're talking about the goldfish one of our refineries keeps to test water that has been used in refinery operations—then purified before it is returned to a nearby river.

These fish *remain healthy* – because the water *remains clean.*

Keeping goldfish happy isn't the main idea, of course. In fact, all Esso refineries don't use this same test. But it does show one of the many steps we take to prevent the pollution of water near our plants.

In the last few years, Esso refineries have spent millions of dollars on projects that aided the fight against air and water pollution.

Esso is doing the same work in *this* community.

BAYWAY REFINERY
G. Ross Murrell, Manager

ESSO

ESSO STANDARD OIL COMPANY

FIGURE 2.—Specific advertising design for a particular community—"Keeping the Smile on the Goldfish."

Other forms of the shotgun approach are the general pamphlets and brochures the company publishes. These are useful for distribution to plants, libraries, municipal and state officials, and interested individuals. Esso's all-time best seller is a short booklet explaining the refinery safety flares (Figure 1). People passing refineries are attracted by this pilot light and want to know why the industry is deliberately creating smoke and wasting a natural resource. The pamphlet clears up their concern on both points.

Allied to booklets and pamphlets is the publication of technical papers on the subject of pollution. Esso's policy is to make technical and other information in this field available as a public service. This has been an effective program.

A fact not to be forgotten is that one company profits equally from other organizations' publications. This kind of cooperation is most important. It helps an individual program, but it also shows interest in the pollution problem to a wide audience.

Another example of the shotgun approach is the use of institutional advertising designed for a particular community. These take the form of paid advertisements run in the local papers. An example of this is shown in Figure 2 where the message is entitled, "Keeping the Smile on the Goldfish." This illustrates the amount of work and money that goes into controlling water pollution with tests made on goldfish living in wastewater from the company refineries. Another which had the highest play-back in a test of readership—"The smoke-stack that wouldn't stay spanked" (Figure 3). It tells of the millions of dollars the company has spent to lick the smoke problem, but admits that the whole problem is not as yet solved.

Rifle Approach

Successful as these approaches have been, it is feared that this is where too many public relations programs stop. There should be far more interest shown in the rifle approach, which has been gaining impetus throughout Esso during the past few years.

One type of rifle shot is illustrated by the cooperation with university and other research projects. Esso does this in a number of places and makes sure that publicity is given to the cooperative work. An example of university-industry cooperation took place at Esso's Baton Rouge plant. This was in connection with the water pollution project which later inspired the goldfish ad. The company also gave scholarships to Louisiana State University to further encourage the study of pollution. This is a double-barrelled way to show real company interest in the problem.

One of the most successful means of getting the story across has been to demonstrate equipment improvements and new installations to municipal and state public health and pollution officials. These plant visits should be on a tell-all, show-all basis, all questions should be answered, and any misunderstanding cleared up. This kind of cooperation with officials goes a long way toward achieving general public understanding. A well-informed public official can, in many cases, do a better job than industry in helping to achieve such understanding.

At Esso's Bayway refinery, the plant personnel has specialized in tailor-made tours for these officials. Recent groups have included the New Jersey State Department of Health, mayors of local communities, the New Jersey Air Pollution Control Commission, and county air pollution commissions. The gentlemen of the press—trade papers as well as the local press—have been invited too, but the statements made by the control officials make far better copy than anything the company may originate.

During the past several years, these visits have become something of an

FIGURE 3.—The most successful of the newspaper paid advertisements.

annual event. Each year the officials can see the progress that has been made since the year before.

This cooperation with municipal officials is not just a once-a-year performance. It goes on all the time. Esso Standard draws on its own people to address clubs and organizations which are interested, or should be interested in pollution. This certainly is a far cry from earlier days when the subject of air and water pollution was among the unmentionables. Now the industry is seeking interested audiences.

Another way of working with municipal organizations is through the use of a booklet for a specific community public relations problem. A few years ago, the Company took over an abandoned quarry at Wind Gap. It was converted into a vast storage reservoir for heating oil. In order to allay any fears the local inhabitants might have about the danger, the odors, or stream pollution, the company published a booklet explaining the precautions that were built in to eliminate these hazards (Figure 4).

Another rifle shot which has been effective has to do with notifying local officials and the local press in advance

when trouble is expected. At times when obvious problems are anticipated, calls are made to the fire and police departments, the department of sanitation, the air pollution department, and the newspapers so they can intelligently handle inquiries from the public. Calls are also made to these same agencies when an emergency occurs. It has been confirmed that this procedure is a character-builder. The important principle here is that the mechanism for making these calls has been well-planned in advance.

Sometimes the refinery is blamed when some other source is really the culprit. It might be simply a combination of natural conditions. Here again, plans have been made in advance to provide a spokesman at each plant, prepared to give answers for what is really happening. He also tries to explain what the company is doing to help solve the problem.

Summary

The keynote for Esso's pollution policy is open communication—at every possible level. The visitor to the plants—the high school chemistry student, the technical man seeking information, the representative of the press, the member of a service club, or the public official—is given all the information that can be mustered to tell the story. A flexible presentation has been worked out—one that can be quickly tailored to a particular group. The happy result is that these efforts have borne fruit in unsolicited articles in the public press (Figure 5).

The moral here is: if the story is told clearly, honestly, and often, the organization will be recognized for its efforts and the attitude of the public is bound to change for the better.

Esso uses both the shotgun and the rifle in its pollution communications. And over the years there has evolved

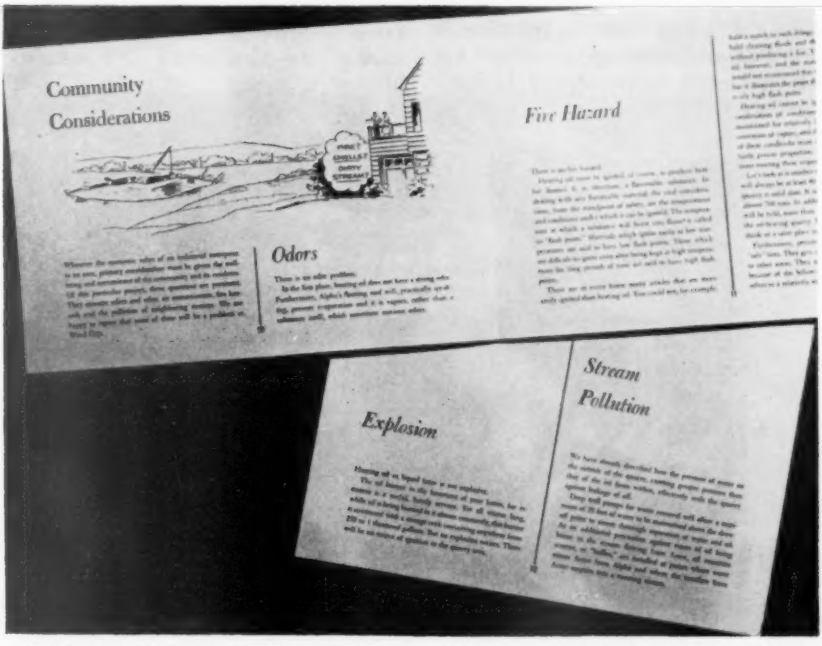


FIGURE 4.—Parts of a booklet used for a specific community public relations problem.

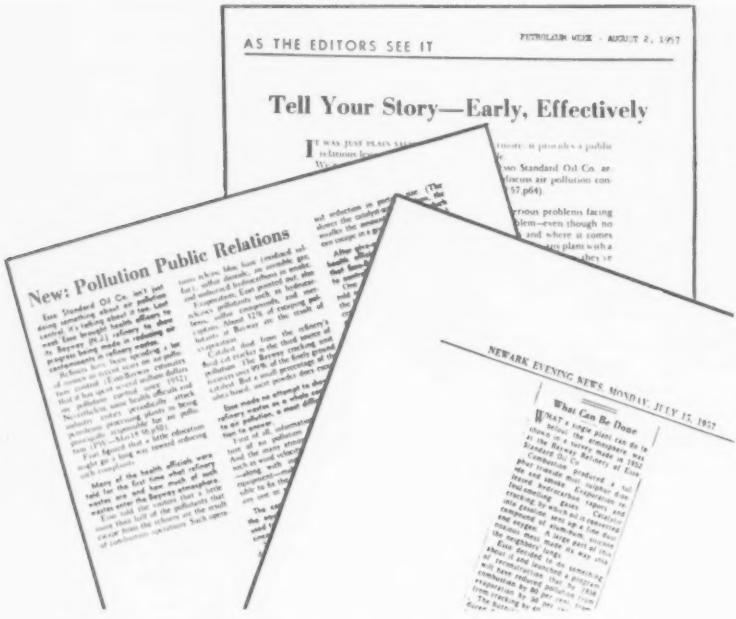

AS THE EDITORS SEE IT
Tell Your Story—Early, Effectively
New: Pollution Public Relations
NEWARK EVENING NEWS MONDAY, JULY 15, 1957
What Can Be Done

FIGURE 5.—Examples of unsolicited publicity in the public press.

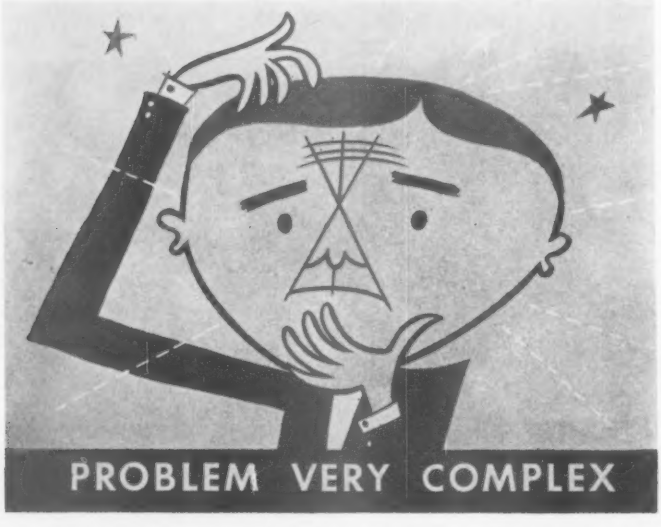


FIGURE 6.—First of a series of posters used to demonstrate to the public the aspects of the industrial pollution problem.

FIGURE 7.—Second of the poster series for public use.

a policy for the public relations aspects of the problem. It can be summed up by considering five themes which are emphasized consistently:

1. The problem is very complex (Figure 6). There is no simple solution (Figure 7). It is also pointed out that the company's program is to work for eventual elimination or substantial abatement of the problem.

2. The industry is constantly working on research to solve the problems of pollution. Backstopping this effort is a continuing sponsored-research program of the American Petroleum Institute which has made many contribu-

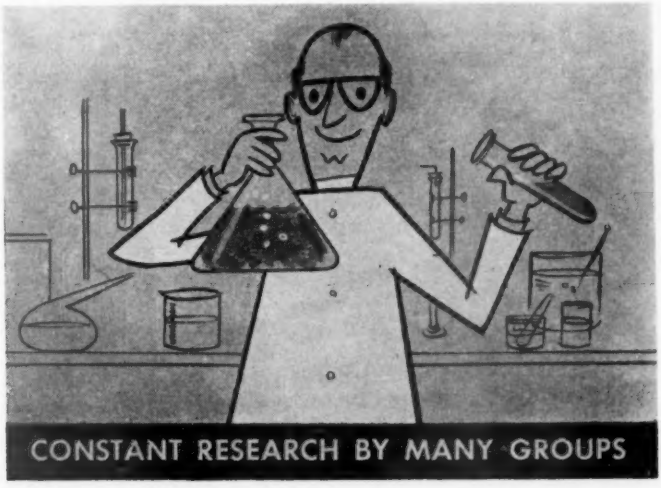


FIGURE 8.—Third in public poster series.

FIGURE 9.—Fourth in public poster series.

tions to knowledge in the field. It is important to make sure that the public realizes this is not a one-shot affair. Research is a continuing process even after partial success has been achieved (Figure 8).

3. The neighbors share in the responsibility for pollution with the specific industry. The company feels it is essential to remind the public that many non-industrial sources contribute a heavy share to the problem (Figure 9).

4. The public should be told why

FIGURE 10.—Fifth in public poster series.

pollution control is costly so that they will appreciate more fully the role industry is playing in keeping air and streams clean (Figure 10).

5. The last of these five themes is a plea for time. Few communities will be able to solve their pollution problems overnight. The public should be told that there is no quick, easy solution, but that the industry expects to do its part and, within reasonable time, to find a solution.

As a last word to this discussion of different ways to inform employees and the community about steps in combating pollution and the five themes Esso always stresses in its public relations program, emphasis should be placed on a basic truth behind all public relations efforts. Behind every successful program of this type is an alert and wide-awake management. No matter how good the public relations effort may be, if top management has not been sold on the importance of pollution control to the over-all success of the company, the program has failed.

This company will continue to exchange information with all groups engaged in study of the problem, for only by pooling information can the most rapid strides be made. This is not a matter of competition. If industry does not solve these problems quickly, it may find that they will be solved by law.

Pollution is in a large measure a public relations problem and as such it involves all in dedication to being a good neighbor, a good corporate citizen, and to the philosophy of the public's best interests.

Communication is the key to the public's understanding of what an industry is doing. If people understand industry, they are more likely to approve its actions. But communications must reflect improvement, and they must be continuous.

UTILITIES IN THE INTERSTATE HIGHWAY RIGHTS OF WAY

The Federation recently found it advisable to comment to the American Association of State Highway Officials in regard to "A Policy on the Accommodation of Utilities on the National System of Interstate and Defense Highways," as adopted by the AASHO Committee on Planning and Design Policies, November 28, 1958.

Since these contacts it has been learned that a number of changes have been incorporated into a revised policy. The requirements now allow certain provisions whereby existing and new utilities may be permitted within the right of way, whereas the former policy was severely restrictive.

According to word from the American Right of Way Association, after ballot by state highway departments it is expected that the U. S. Bureau of Public Roads will adopt this as the final policy.

Further information may be obtained from the Secretary, Committee on Planning and Design Policies, American Association of State Highway Officials, Bureau of Public Roads, Washington 25, D. C.

INDUSTRIAL AND MUNICIPAL COOPERATION FOR JOINT TREATMENT OF WASTES *

I. INDUSTRY APPROACH AND POSITION

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The American Cyanamid Company manufactures more than 800 chemical products in its plant at Bound Brook, New Jersey. The industrial wastes from these operations include process waters from the manufacture of rubber chemicals, plastics, pharmaceuticals, pigments, several hundreds of dyes and large tonnages of "intermediate" chemicals, as well as cooling waters, sanitary sewage, and storm runoff from the plant area. The total flow from all of these sources averages about 17 mgd and has a 5-day BOD averaging about 300 mg/l. After treatment, the flow is discharged to the Raritan River through a dispersion dam which was constructed by the Company for this purpose.

Earlier discussions with respect to the Raritan River pollution problem have been discussed partially in several papers (1) (2) (3) (4) (5) (6) (7) (8) (9) (10). During the past 10 years, the Company has had to choose between three basic alternate solutions to its Bound Brook waste disposal problem:

1. Joining the Middlesex County Sewerage Authority.
2. Joining the Somerset Raritan Valley Sewerage Authority.
3. Construction and operating its own treatment plant.

Selection of the best method, from the point of view of all concerned, has required a great amount of research and comprehensive study by Company personnel and its consultants.

General Considerations

In recent years many industries and municipalities have been faced with deciding whether industrial wastes should be discharged into municipal systems for joint treatment and disposal. The steadily increasing number of publications on this subject indicate its growing importance to members of the wastes treatment field. Opinions expressed in the literature cover a wide range, extending from the belief that little or no industrial wastes should be discharged into municipal systems to the opposite viewpoint that it is the duty of municipalities to provide wastes collection and treatment facilities for all taxpayers, including industries, insofar as possible. In the light of current progress and trends in stream pollution abatement, and the wide divergence of views on the subject of joint treatment, this method of disposal may be expected to receive even more attention in the future.

Joint treatment of wastes poses many questions, to industry and municipality alike, which are beyond the purely

* Presented at the 31st Annual Meeting, Federation of Sewage and Industrial Wastes Assns.; Detroit, Mich.; Oct. 6–9, 1958.

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technical considerations of whether the mixed wastes could be treated satisfactorily and whether joint treatment would be the most economical solution for all concerned. Other areas of importance include public relations aspects, legal considerations, and local attitudes toward industrial development. The difficulties in determining the best solution are compounded by the fact that agreements between municipalities and industries for joint treatment of wastes usually extend over very long periods of time. In most cases, it is very difficult for personnel responsible for planning municipal facilities to evaluate future industrial growth and problems which may arise in future treatment of ever-changing industrial wastes. Similarly, it is difficult for an industry to predict satisfactorily the future limitations and service charges which may be placed on waste discharges, as well as the future attitude and political views of changing municipal administrations.

This entire question is one which must be approached and considered most carefully and, above all, realistically if present and future problems are to be solved to the lasting satisfaction of all parties. As with many other problems in the waste treatment field, there is no single general solution; each individual situation must be evaluated on its own merits. In general, however, it may be said that the complexity of the problem, and the thoroughness with which it should be studied prior to reaching a decision, increases sharply with industrial wastes loadings which represent relatively large proportions of the total to be handled by a municipal system. This is especially true with respect to determining treatability of the industrial wastes by processes used, or to be used, in the municipal system, as well as the type and extent of pretreatment which should be required prior to discharge into that system. This information is required to insure that both parties to the agreement fully understand any problems which might be involved in its execution initially, as well as potential problems which could become important several years hence.

At the various manufacturing plants within the framework of American Cyanamid Company, there is almost every conceivable general arrangement for disposal of industrial wastes. At many locations, wastes are treated in company-owned facilities and discharged directly to receiving bodies of water without any connection with municipal systems. At other plants, wastes are discharged to municipal sewage handling systems without pretreatment or after physical, chemical, or biological treatment, depending on the circumstances in each case. Thus, it may be seen that the Company has no firmly fixed policy for or against discharge of plant wastes into municipal systems. At the Bound Brook plant, as with prior decisions at other plants, the approach was to obtain all facts pertaining to each of the three possible solutions. The alternatives then were weighed, taking into consideration all factors for and against each, to provide a sound basis for determining which solution would be best for this specific problem.

Middlesex County Sewerage Authority

In 1948 the Middlesex County Planning Board proposed a method for reducing pollution of the Raritan River, based on collecting all wastes from the heavily populated and industrialized region (Figure 1) for joint treatment and disposal. In July 1950, the Middlesex County Sewerage Authority was created by the Middlesex County Board of Freeholders. The Authority was given power to abate stream pollution within Middlesex County and to contract for treatment of wastes from municipalities and industries outside Middlesex County.

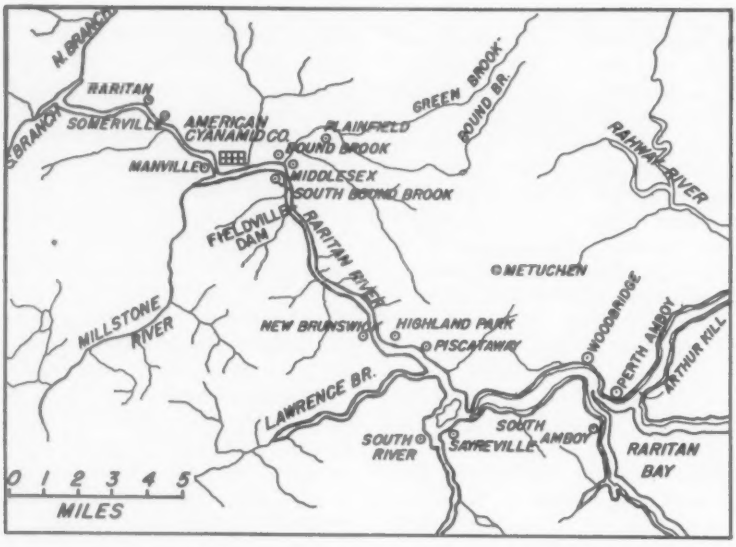

FIGURE 1.—Map of area surrounding the American Cyanamid Company and Bound Brook, N. J.

The project recently completed and placed in operation by this Authority includes a 27-mile intercepting sewer from Bound Brook to Sayreville and a waste treatment plant located near Sayreville. Municipal and industrial wastes collected along the route of the interceptor are subjected to chemical coagulation and sedimentation for removal of sludge which is barged to sea. After chlorination the plant effluent is discharged into Raritan Bay through a submerged outfall sewer.

All major municipalities and industries near the river in Somerset County were invited to join this system. After careful consideration of all aspects of the problem, those municipalities and industries located in Somerset County upriver from Bound Brook elected not to join the Middlesex County Sewerage Authority. These included, among others: the Boroughs of Somerville and Raritan, the Township of Bridegwater, the American Cyanamid Company, and the Johns-Manville Corporation.

Somerset Raritan Valley Sewerage Authority

A suggestion was offered that an investigation be made of the advisability of designing and constructing joint treatment facilities for municipal and industrial wastes from the upper region of the Raritan Valley. The above-mentioned municipalities and industries agreed with this idea, and in August 1952, the Somerset County Citizens Committee was formed.

Consulting engineers were retained to make preliminary feasibility studies and in April 1953 a comprehensive engineering report (11) was submitted to the Committee. The report recommended creation of a Somerset Raritan Valley Sewerage Authority for collection and joint treatment of all municipal and industrial wastes in the upper valley. In addition, it was recommended that storage be provided in the Raritan River to impound water during high river flows for later release at times of low natural flows, thus improving sanitary conditions down-

TABLE I.—1953 Estimated Flows and BOD Loadings, Somerset Raritan Valley Sewerage Authority

Wastewater Source	Average Flow (mgd)	Per Cent of Total Flow	Average BOD (lb/day)	Per Cent of Total BOD
Somerville	1.88	7	2,880	7
Raritan	0.65	2	1,060	2
Bridgewater*	0.30	1	490	1
Johns-Manville	6.92†	25	8,825‡	22
Cyanamid	18.0	65	27,700§	68
Total	27.75	100	40,955	100

* Estimated.
† To be reduced to 5.2 mgd.
‡ To be reduced to 4,325 lb/day.
§ To be reduced to 15,000 lb/day.

stream during dry periods. Subsequently, the Authority was formed by the municipalities and planning was initiated for construction of an intercepting sewer and treatment plant. The two industries were invited by the Authority to join this system.

Table I summarizes the flows and characteristics of wastes from each municipality and industry, as estimated in the 1953 engineering report to the Somerset County Citizens Committee (11).

At that time the apparent BOD loading from the Cyanamid Plant averaged about 27,700 lb/day, or 68 per cent of the total of all contributors. It was anticipated that intraplant improvements would make it possible to reduce this BOD load to approximately 15,000 lb/day through source treatment and modification of manufacturing processes. These proposed changes, and the anticipated reduction in waste flow and BOD loading from Johns-Manville, made it appear at that time that a realistic estimate should place Cyanamid's share at 63 per cent of the total BOD loading and 69 per cent of the total flow.

Pilot-Plant Work

In 1949 Cyanamid had initiated laboratory and pilot-plant studies to determine the treatability of its Bound Brook wastes by biological methods. A thorough investigation of this question was necessary because of the highly complex nature of Cyanamid's wastes and the feeling held by many sanitary engineers that biological treatment might prove most difficult, or perhaps even impossible.

From the quantity and characteristics (Table I) it was evident that the treatability of these wastes would be of critical importance in designing, constructing, and operating the combined treatment plant. Therefore, it was impossible for Cyanamid and the Authority to arrive at a sound decision on the feasibility of joint treatment until pilot-plant work had provided reliable answers to several basic questions. This situation made it necessary for Cyanamid to continue investigating biological treatment of its wastes, both alone and in combination with other industrial and municipal wastes. Accordingly, Cyanamid constructed and operated a large pilot plant concurrent with the work of the Somerset County Citizens Committee, and later the Somerset Raritan Valley Sewerage Authority.

The extensive pilot-plant equipment and investigations have been partially described earlier (5) (6) (7) (8) (9) (10). Many modifications of the trickling filter and activated sludge processes were investigated over a period of several years. It was found that modified versions of either process could provide satisfactory treatment, but that the nature of Cyanamid's wastes would require an installation much larger than that necessary for an equivalent volume of sanitary sewage. Addition of sewage to the Company's wastes, in ratios approximately equal to those which would be encountered in a joint treatment works, did not affect the efficiency of either treatment process significantly.

Special studies carried out in connection with pilot-plant investigations during the period 1953 to 1955 disclosed an extremely important fact

concerning the BOD loading contributed by the Cyanamid Plant. In laboratory determinations of BOD it was found that use of an acclimatized seed resulted in significantly higher BOD values than those which had been obtained earlier. This change in analytical procedure, together with substantial increases in manufacturing production, resulted in a net increase in the apparent over-all BOD load, instead of the decrease which had been anticipated. The increase occurred in spite of actual reductions in certain waste discharges through improvements in the manufacturing areas.

Company Decision and Reasons

Late in 1955 all of the studies had progressed sufficiently to provide a sound basis on which could be determined the best course of action for solution of the problem. After careful consideration the Company announced that it would not join as a participant in the Authority. Some of the most important conclusions which led to this decision follow.

Share of Load

The increase in BOD loading for plant design from an originally anticipated 15,000 lb/day to an actual 40,000 lb/day in 1955 meant that the Company wastes would have contributed 82 per cent of the total BOD to be handled by the combined system, assuming that Johns-Manville elected to join the Authority. If Johns-Manville did not participate in the Authority, the Company's share of total BOD loading would have been increased to 90 per cent. It is readily seen that construction and operation of a joint system would have been controlled, primarily, by the characteristics and volume of Cyanamid's wastes. With such disproportionate ratios, it appeared much more reasonable that the Company, producing 80 to 90 per cent of the total wastes, should assume responsibility for their treatment.

Not only were BOD loadings disproportionate, but also pilot-plant work had shown that these wastes would require a larger installation than an equivalent volume of sanitary sewage. Therefore, regardless of whether the plant were constructed by the Company or by the Authority, the facility would have to be of unusual design and substantially larger than most municipal plants handling equivalent flows. This means that it would have been necessary for the Authority to finance, construct, and operate a plant many times the size and cost of one which normally would be required for the area and population served.

Plant Production

In the fast-moving chemical industry, in particular, it is possible for manufacturing production and wastes characteristics to vary often and rapidly. This certainly would be true in a manufacturing plant of the size and diversification of the one at Bound Brook. Installation of new manufacturing operations which might materially change the character of plant wastes invariably leads to the question of whether the new wastes should be: (a) treated at source, (b) partially treated at source prior to treatment with other mixed plant wastes, or (c) discharged directly to the plant collection and treatment system. These three methods of handling a new waste always should be considered carefully, with the final choice being based on efficiency of treatment and economy.

Discharge of a major new waste to the Authority without complete prior evaluation of its treatability could have serious effects on plant operation, resulting in unsatisfactory treatment efficiency, or perhaps, the necessity for shutting down a manufacturing process for extended periods of time. In some cases, extensive experimentation and modification of operating proced-

ures might be required in the treatment plant to cope with new wastes.

Joint Responsibility

Therefore, it is evident that thorough advance planning for handling a new waste requires intimate knowledge of the proposed new manufacturing process, as well as of the wastes treatment plant operation, to permit rational selection of the optimum method for disposal. It would have been unsatistory, from the Authority's point of view, to give Company personnel unilateral responsibility for determining the volumes and types of wastes which could be discharged into an Authority-owned plant. On the other hand, the highly confidential nature of many new manufacturing operations could make it impractical for the Company to disclose details of possible future manufacturing processes in early stages of development.

In many cases the most economical solution for handling a new waste would be to discharge that waste directly to the central wastes treatment plant, even though, in some cases, this might require extensive modification or enlargement of that plant. A public-financed Authority might find it difficult, or even impossible, to undertake these changes and the additional capital investment to accommodate one customer, especially in view of the unusually large financial investment already required for initial plant construction.

Advantages of Industry Treatment

The above two problems would be eliminated if the Company constructed and operated its own wastes treatment facilities. Advance confidential information available to Company personnel would make it possible to explore thoroughly all methods of disposal before adopting a new manufacturing process, and would provide complete freedom in selecting the optimum method. If it proved necessary to modify or enlarge the treatment plant, the Company would be in a position to finance and carry out these changes during construction of the new manufacturing plant. It is evident that the Company and the Authority would have much greater flexibility, and that many potentially serious problems for both could be minimized, if the Company assumed responsibility for treating its own wastes.

With public financing it is customary to provide substantial excess capacity in the treatment plant design. This margin allows for future growth of municipalities and industries without additional financing of capital expenditures. The Raritan Valley area of New Jersey is growing at a rate about double that for the State as a whole. Hence, it would be reasonable to conclude that a public authority would be required to include generous capacity allowances in treatment plant design in anticipation of future growth. On the other hand, the Company had reason to believe that further pilot-plant and full-scale studies of the treatment process could make it possible, in future years, to attain higher loadings in the treatment plant than those to be used in the initial design. If Cyanamid constructed the plant, it would be possible to provide a reasonable, but smaller, design margin, anticipating future improvements in plant efficiency. If these improvements did not materialize, or if the BOD loading increased radically, the Company would be in a position to modify its treatment plant quickly. This approach would be facilitated by the knowledge by Company personnel of advance production plans. Thus, it is evident that treatment plant construction by the Company could result in appreciable economies initially and, perhaps, indefinitely.

Type of Treatment

At this time (1955), a final decision had not been reached on whether to use trickling filters or an activated sludge type of process. The encouraging results being obtained with activated sludge pilot units indicated that substantial economies, and more efficient operation, might be realized with this type of plant. However, further pilot-plant studies were required to establish the optimum process and the loading factors for plant design. Many individuals have been skeptical concerning use of the activated sludge process for treatment of industrial wastes, and it is generally recognized that close attention usually is necessary for successful operation of a large activated sludge plant. All of these considerations made it appear dubious that the Authority would be in a position to undertake construction of this type of plant. On the other hand, the Company could, at its own risk, continue activated sludge pilot-plant studies leading to construction and operation of a plant based on this process. In the event of future difficulties in its operation, the Company would be in a position to move rapidly to correct the problems through treatment plant modification or source treatment of some wastes.

A very important item which deserves serious consideration in designing a biological treatment plant is the disposal of sludge. It was envisioned that sludge lagoons could be used on company property, whereas there was some question whether this would be a choice at an Authority treatment plant. Should it be necessary to provide sludge dewatering and digestion facilities, appreciable costs would be added.

All factors considered, it appeared that it would be more efficient and economical for all parties if Cyanamid were to assume full responsibility for constructing and operating its own wastes treatment works.

Alternate Arrangement

The results from pilot-plant operations indicated that either type of biological treatment process could handle Cyanamid's wastes alone or in combination with sewage from the municipalities. In the activated sludge units, for example, addition of 10 to 20 per cent municipal sewage to Cyanamid's wastes resulted in the same quality of effluent, in spite of shorter aeration periods with larger flows being treated. Additions of phosphorus to the industrial wastes to satisfy nutritional deficiencies could be decreased slightly because of small quantities of this element in the municipal sewages. These findings indicated that, while the Company should construct and operate its own treatment plant, it still would be feasible to undertake biological treatment of mixed industrial and domestic wastes. Therefore, the question of joint treatment was pursued further to determine whether a practical solution might be found.

Responsibility for Entire System

A system capable of handling all wastes from Authority participants would include construction of a large intercepting sewer and a complete primary treatment plant for the municipal sewage, followed by joint biological treatment with Cyanamid's wastes. Neither the interceptor nor the primary plant would involve the Company wastes in any respect. Construction and operation of all facilities by Cyanamid would have involved many legal problems and would have imposed a heavy financial burden on the Company. In short, Cyanamid would have been required to enter into the sewage collection and treatment business which is, of course, far removed from the purpose of a chemical manufacturing company. Furthermore, Cyanamid would have been faced with collection and treatment of municipal and industrial wastes for an indefinite period, with

uncertain means for controlling the quality and quantity of wastes received into the system. With rapid future growth of the area, it might prove necessary to undertake extensive enlargement of the system to accommodate increased loadings of municipal and industrial wastes. It appeared essential that, in the interest of future community development, the Authority should retain complete flexibility to enlarge or modify its collection and treatment system, independent of Cyanamid, to satisfy the changing requirements of the area. Therefore, for the Company to be responsible for the entire system would not have been reasonable or wise from the points of view of the Authority or the Company because it could have been much too permanent and inflexible for both parties.

Separate Primary Treatment

A more reasonable approach for both parties appeared to be for the Somerset Authority to construct and operate an intercepting sewer system and primary treatment plant of a type and size deemed to be adequate for the area served. This system would be entirely separate from Cyanamid's system, both physically and administratively. Cyanamid then could accept the effluent from the primary treatment plant for joint secondary treatment with its wastes. This arrangement would provide the advantages of joint treatment while allowing each party flexibility to operate, modify, and enlarge its system as desired.

Accordingly, in November 1955, Cyanamid offered to accept for secondary treatment settled sanitary sewage from the Somerset Authority primary treatment plant. The volume and character of such sewage would be within reasonable limits set forth in a contract to be negotiated between the parties, allowing for anticipated future growth of the area. Cyanamid proposed that an agreement could be made for a period of 10 years, to be reappraised at the end of 7 years. At that time it could be continued by mutual agreement for another 10-yr period or, if desired, terminated by either party on expiration of a 3-yr written notice. These periods subsequently were changed to 20 and 17 yr, respectively, at the request of the Authority. The Company stated that no charge would be levied for amortization of the treatment works or routine operating costs, but only for the additional out-of-pocket costs of extra electrical power, chlorine, and laboratory labor required for sampling and analyzing the Authority's primary effluent.

Terms of Agreement

Following this plan, the Authority would receive definite benefits. The capital costs for secondary treatment could be postponed for at least 17 yr and, if both parties wished to continue the arrangement, for a much longer period. If at the end of a 17-yr period the contract should be terminated by either party, the Authority then would be in a better position to evaluate the type and size of secondary treatment plant required and would have 3 yr to construct that plant. Cyanamid would be in a position to know in advance the amount and type of municipal wastes which it might have to accept for treatment. If the specified volumes were exceeded at some future date, the Authority and the Company could elect, at their options, to renegotiate a new contract. In the event either party so desired, the agreement could be terminated at that time and the Authority could add secondary treatment to its own facilities.

In the event Cyanamid should discontinue the manufacture of chemicals at its Bound Brook plant, it would make available to the Authority specified portions of the treatment plant. These units would make it possible for the Authority to continue secondary treatment of its primary effluent dur-

ing the remainder of the contract period.

Cyanamid's proposal to build its own treatment plant and its offer to accept the settled sanitary sewage for secondary treatment were agreeable to the Authority and the State Department of Health. The Authority's consultants studied the proposal in detail and recommended (12) that Cyanamid's offer should be accepted, subject to satisfactory negotiations. The members of the Authority, its financial advisors and attorneys accepted this recommendation and the Authority advised Cyanamid of its desire to discuss the terms of a contract.

In September 1957, arrangements were completed for the formal contract between the Company and the Authority, which is in effect at present. Facilities for receiving primary effluent from the Authority's plant were included in the new activated sludge treatment plant recently placed in operation by Cyanamid.

Summary

The relationships between American Cyanamid Company's Bound Brook plant and the Somerset Raritan Valley Sewerage Authority have been discussed from the Company's point of view.

It is felt that the final arrangement between the Company and the Authority is the best one which could have been reached, from the point of view of all concerned. Both the Authority and the Company retain a high degree of flexibility in their operations. At the same time, the arrangement provides the advantages of joint treatment of municipal and industrial wastes.

The Company is pleased that the many years of cooperative efforts with its neighbors have culminated in a satisfactory agreement for joint solution of stream pollution problems in the upper region of the Raritan Valley. It is looking forward to many years of continued cooperation for effective solution of future problems.

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II. MUNICIPALITY APPROACH AND POSITION

By Roy H. Ritter

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The sewage treatment plants for the Boroughs of Somerville and Raritan, New Jersey, both in Somerset County, were constructed about 20 years ago and became inadequate for satisfactory treatment about 10 years ago. The imminent construction of a major sewage handling works by an Authority in the nearby and downstream County of Middlesex made the question of adequate sewage treatment in Somerset County more urgent.

Wastewater Flow

Table II shows the population and sewage flow of the three participants in the Somerset Raritan Valley Sewerage Authority.

Bridgewater Township, with a population of well over 8,000, is unsewered but sewer installation is imminent. The Borough of Manville with a 1950 census population of 8,597 and a sewage flow slightly less than 1.0 mgd, including Johns-Manville sanitary wastes, has an adequate treatment plant at present and is not a participant in any authority.

These four municipalities (those in Table II and Manville), with a combined sewage flow of approximately 3.6 mgd, are well upstream from the two large industries, American Cyanamid Company, with about 15 to 20 mgd of flow, and Johns-Manville Corporation, with about 5 to 8 mgd of flow. The industrial waste was, therefore, from 5 to 7 times greater than the local municipal waste.

TABLE II.—Sewage Flow and Population of Somerset Raritan Valley Sewerage Authority Participants

Participants	1950 Census	Average Sewage Flow 1952–1955 (mgd)
Borough of Somerville	11,571	1.91
Borough of Raritan	5,131	0.69
Bridgewater Township	8,234	0*
Total	24,936	2.60

* No sewers.

Industry Action

The two large industries decided not to join the downstream Middlesex Valley Sewage Authority. Because the Borough of Manville plant was adequate and because the Somerville Municipal Plant was approximately seven miles beyond the end of the Middlesex Authority interceptor, it would have been prohibitive in cost for the municipalities to independently join the Middlesex Authority and in effect leapfrog the two large industrial plants.

The two industrial plants, the American Cyanamid Company and the Johns-Manville Corporation, realizing the impact of their decision upon the four municipalities, financed a Citizens Committee Report issued in 1953 to investigate the possibility of an Authority to serve Somerset County and to undertake the treatment of the waste from the industries and municipalities in a joint plant. This report estimated that a $7.0 million project would serve their needs. It further contemplated a high-rate trickling filter plant, but recommended extensive pilot-plant tests on the highly complex industrial waste before proceeding with construction.

American Cyanamid Co.

In November 1955, after extensive and expensive pilot-plant studies, the American Cyanamid Company decided to construct a modified activated sludge plant at its own expense and made a most generous offer to treat the secondary effluent of the Authority

plant at its additional operating cost and to make no charge for capital investment.

The offer of the American Cyanamid Company was reviewed by the Authority, with and without the waste from the Johns-Manville plant. In either case it appeared that the offer was well worth accepting.

Johns-Manville Corp.

In the meantime, Johns-Manville had been intensively investigating its own trade waste which consisted principally of 5 to 8 mgd of alkaline waste from the cement-asbestos process and about 0.1 mgd of highly concentrated waste from the roofing paper process.

Johns-Manville finally decided that its existing plant with some additional facilities could treat its waste satisfactorily and accordingly did not join the Authority.

The Johns-Manville plant discharges its domestic waste to the Borough of Manville treatment plant and it was decided to continue this method and to enlarge the 1 mgd domestic plant if necessary in the future. The Borough of Manville's sewage treatment plant discharges its effluent downstream from intakes of the Elizabethtown Water Company's plant and could be expected to continue to give good treatment for some time in the future.

Alternate Plan

The Somerset Raritan Valley Sewerage Authority which was formed in November 1953 includes only the Borough of Somerville, the Borough of Raritan, and Bridgewater Township. Figure 2 shows the area to be served by the Authority. This Authority of only three municipalities studied three possible methods of handling its waste.

1. Plan A: a 4.5-mile interceptor and a 5 mgd primary plant, discharging its waste to Cyanamid's secondary plant.
2. Plan B: abandon the Authority and each Borough build its own plant.
3. Plan C: join the Middlesex Authority.

TABLE III.—Preliminary Estimate of Project Cost

Item	Cost ($)
Interceptors (4.8 miles of 36-, 42-, and 48-in.)	1,400,000
Treatment plant (5 mgd primary)	900,000
Contingencies	225,000
Total construction	2,525,000
Interest during construction (1 yr @ 4 per cent)	112,000
Engineering	160,000
Legal	15,000
Administrative	48,000
Coverage for reserve fund (1 yr)	180,000
Land	10,000
Total	3,050,000
Less Federal Grant	−250,000
Bond Issue	2,800,000

The independent municipal plants under Plan B were estimated to cost slightly less than the Authority plant but would have provided: (a) no capacity for expansion, (b) would discharge its waste above the intakes of the Elizabethtown Water Company, and (c) Bridgewater Township would not be able to provide sewers except at prohibitive cost and with many small sewage plants. The charges of the Middlesex Authority under Plan C were more than that of the Authority plant under Plan A.

Finally, after thorough and patient studies of all possibilities over a period of approximately a year, the Authority formally accepted the American Cyanamid offer in early 1957. This decision to proceed was based on Plan A and the estimated costs shown in Table III.

The grant of $250,000 from the Federal Government under P.L. 660 helped reduce the cost about 8 per cent and was a contributing factor to the adoption of Plan A by the municipalities. The contract for construction of the interceptor sewer and treatment plant of Plan A was awarded in April 1958. The Authority's project was scheduled to be in operation in the spring of 1959. The final construction cost of

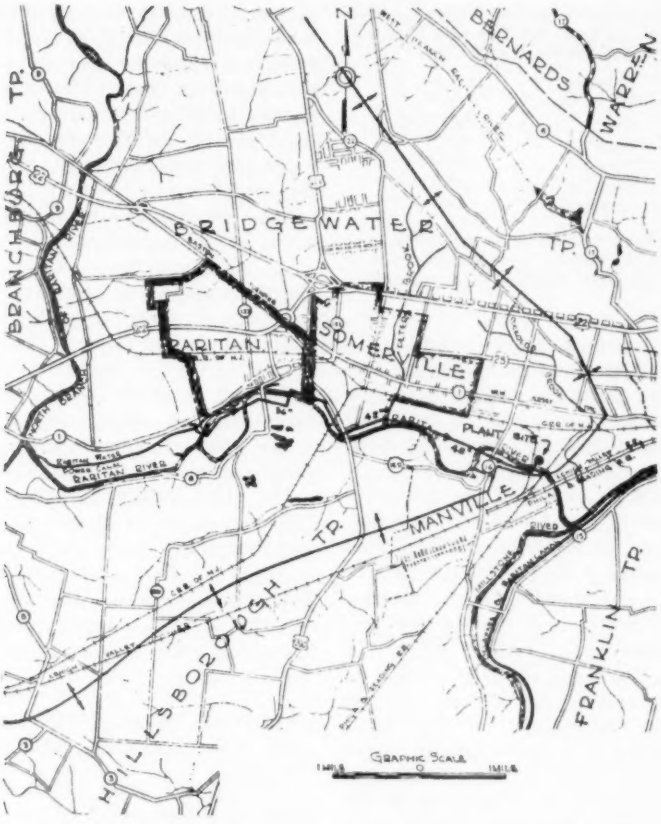

FIGURE 2.—Area encompassed by the Somerset Raritan Valley Sewerage Authority.

the project will be about 15 per cent less than the preliminary estimated cost because of unusually low contractors' bids received in February 1958. The American Cyanamid's waste treatment plant has been completed and will have several months of operating experience before receiving the effluent from the primary treatment plant of the Authority.

Agreement Between the Authority and Participants

The agreement between the Authority and its three participants, the Borough of Somerville, the Borough of Raritan, and Bridgewater Township, was finally adopted in September 1957. This agreement includes the customary provision concerning metering, payment, connections, extensions, enforcements, and other contractual clauses.

Rate Schedules

The initial schedule of rates included in the agreement between the Authority and its participants is given in Table IV.

No revenue is anticipated from the surcharge for excess BOD or suspended solids because tests show that the present annual average is under 200 mg/l. Such a surcharge, of course, is necessary to control the discharge of some

TABLE IV.—Waste Treatment Rate Schedule for Participants in the Somerset Raritan Valley Sewerage Authority

Quantity (mil gal/mo)	Charge* ($/mil gal)
First 3	180
Next 9	150
Next 40	120
Next 40	105
All over 92	90

* In addition to these charges the following surcharges are assessed for annual average in excess of 250 mg/l: BOD—$0.01/lb, and SS—$0.02/lb.

possible future industrial waste. The contract between the Authority and Cyanamid requires the Authority to pay Cyanamid a surcharge for BOD in excess of 200 mg/l and suspended solids in excess of 100 mg/l.

It is not believed that the Authority will have to pay Cyanamid any surcharge for excess BOD or suspended solids unless it is simultaneously collecting a surcharge from its Participants. This is true because the primary plant would have to reduce the limiting 250 mg/l of BOD in the influent by only 20 per cent to meet the 200 mg/l requirement for its effluent to Cyanamid. The primary plant would also have to reduce the suspended solids of the influent from 200 mg/l by only 50 per cent to 100 mg/l in the effluent to Cyanamid.

The customary restrictions on the character of the effluent to be received by the Authority are spelled out in the agreement between the Authority and Cyanamid, and these identical requirements are also included in the agreement between the Authority and its participants. These requirements are listed elsewhere herein.

Financing

The controlling factor in a project of this character is, of course, the method of financing. One of the Participants at this time has no sewer system and, therefore, no sewage flow; so that payment on a volumetric basis would produce no revenue. It was agreed that each of the participating municipalities would agree to underwrite or agree to pay a minimum annual service charge (Table V) based on an assured minimum sewage flow.

At present the Township of Bridgewater has no sewage flow so that for the next few years they will make an annual payment but will discharge much less sewage flow than their assured minimum flow. Each Participant has agreed to discharge a minimum annual flow which in effect is a minimum annual charge. This makes it possible for the Authority to adjust their rate schedule as needed in the future and in effect increase or decrease the minimum annual service charge of each Participant.

The plant capacity is 5 mgd so that 1.22 mgd or about 25 per cent of the plant capacity is unallocated or "unassured" so that each of the three Participants can use this unallocated capacity, or by contract neighboring townships may become customers of the Authority.

Agreement Between the Authority and American Cyanamid Company

After several engineering and legal revisions, a final agreement was signed in September 1957 between the Authority and the American Cyanamid Company. This agreement includes customary legal requirements and a single basis of (a) allocating operating costs, (b) defining quality of Authority efflu-

TABLE V.—Statement of Minimum Annual Service Charges

Municipality	Assured Minimum Flow for Annual Service Charge (mgd)	Minimum Annual Service Charge ($)
Borough of Somerville	1.92	88,308
Borough of Raritan	0.93	46,152
Township of Bridgewater	0.93	46,152
Total	3.78	180,612

ent, and (c) defining the volume of effluent to be received.

The agreement includes a detailed description of the pipe lines and work to be performed by the Authority on the Cyanamid property in easements assigned to the Authority. The minor amount of piping inside of Cyanamid structures to accommodate the Authority sewage was paid for and is owned by Cyanamid and all work constructed by the Authority outside of the Cyanamid structures is owned and maintained by the Authority.

Limiting Characteristics of Waste

Cyanamid granted the Authority permanent easement for discharge of its effluent through its property in the event this 20-yr agreement is terminated in the future. The settled effluent delivered by the Authority into Cyanamid's treatment plant shall not contain injurious or deleterious concentrations of any of the following substances:

1. Gasoline, cleaning solvents, fuel oil, miscellaneous other oils, and similar substances.
2. Materials containing objectionable concentration of color.
3. Ashes, sand, cinders, and similar substances.
4. Tar, plastics, and other viscous substances.
5. Mineral oils.
6. Feathers, hair, rags, and similar substances.
7. Metal, broken glass, shavings, and similar substances.
8. Unshredded garbage.
9. Toxic, corrosive, explosive, or malodorous gases.
10. Acetylene generation sludge and similar substances.
11. Radioactive substances.

Likewise, without limiting the generality of the foregoing and by way of illustrative specification only, settled effluent containing concentrations in excess of the following maximum will not be delivered to or received into Cyanamid's treatment plant.

Item	Maximum (mg/l)
Total iron	5
Copper	3
Chromium	5
Cyanides	2
Phenol	25
Oils, mineral	15
Grease and soluble oils	25
Free mineral acid	None
Acetylene generation sludge	None

Likewise, without limiting the generality of the foregoing and by way of illustrative specification only, the settled effluent to be delivered by the Authority may be rejected by Cyanamid if its strength and character shall exceed the following concentrations:

Item	Limits
Temperature	110°F
pH	5.5–9.0
BOD (based on avg of 5 consecutive daily composite samples)	200 mg/l
SS (based on avg of 5 consecutive daily composite samples)	100 mg/l

Cyanamid at its option may receive the primary settled effluent from the Authority plant with a BOD in excess of 200 mg/l and in such case the Authority will pay Cyanamid $0.01 per pound of BOD in excess of 200 mg/l concentration computed on an annual average basis.

Cyanamid at its option may receive the primary settled effluent from the Authority plant containing more than 100 mg/l of suspended solids and in such case the Authority will pay Cyanamid $0.01 per pound of suspended solids in excess of 100 mg/l concentration computed on an annual average basis.

Data indicate that the effluent characteristics from the primary treatment plant will be within the limits set by the specifications. However, some limitation is necessary for possible future industrial wastes from the participants.

Operating Cost

The Authority will pay to Cyanamid portions of Cyanamid's operating cost as follows:

Item	$/mil gal
Electrical power	3.45
Test, control, and service charge	.99
Chlorine cost (at 2/3 of the cost of chlorine needed to maintain same residual in Authority's effluent as required by the State Health Department for Cyanamid's effluent)	2.70*
Total	7.14

* Estimated.

These operating costs are appreciably less than comparable costs in many municipal activated sludge plants. These charges may be changed in the future in proportion to changes in electrical and labor costs.

Other Considerations

The most valuable part of this agreement to the municipalities is the following:

> The Authority shall not be required to pay any part of interest or amortization charges on the construction cost of facilities to be installed and used by Cyanamid to provide secondary treatment of the settled effluent discharged from the Authority's primary treatment plant; nor for the costs of management or maintenance or operation of Cyanamid's secondary treatment plant.

It has been estimated that secondary treatment for the plant of 5 mgd capacity would cost approximately $500,000. This offer of Cyanamid will, therefore, make a total saving of about $1,000,000, when operating cost, interest, and amortization are included. If the Authority were required to construct and operate the secondary facilities, the charges to the participants would have to be increased about 25 per cent.

The agreement was originally for 10 years but at the Authority's request Cyanamid agreed to enter into a contract for a period of 20 years with renewal features. Cyanamid also agreed that in the event of the abandonment of its activated sludge plant, about one-third of the plant would be assigned to the Authority for its use.

The Authority's plant is a conventional 5-mgd primary plant with all units sized in accordance with the standards of the State Department of Health of New Jersey.

An ideally located tract of land of approximately 75 acres was available and by mutual agreement the Authority purchased 14 acres for its present 5-mgd primary plant and possible future 20-mgd complete treatment plant with Cyanamid obtaining the remainder of the tract. The Authority will pump its sewage once only and its effluent will flow by gravity to the Cyanamid plant and thence to the river.

The interceptor has a capacity of 10 mgd so that the plant can be expanded to 10 mgd from the present 5 mgd if needed in the future. The 14 acres are sufficient for a 20-mgd complete treatment plant if ever needed by the Authority.

DALLAS–1959

USE CONVENIENCE OF PREREGISTRATION

AVOID DELAY AT DESK ON ARRIVAL

SEE PAGE 1119 FOR DETAILS

INDUSTRIAL WASTE CONTROL IN THE FORD MOTOR COMPANY *

By F. J. Kallin

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The term "industrial waste control" is difficult to define because of the many requirements which must be taken into consideration in planning an effective industrial waste control program. Although usually thought of as being limited to the planning, design, construction, and initial operation of new facilities, the concept of industrial waste control should be broadened to include the following: (a) the treatment variations required for the modified process loadings resulting from changes in manufacturing and production techniques; (b) difficulties encountered in disposing of waste treatment sludges and oils; and (c) selection, training, and replacement of operating personnel. Such matters as these are so integrally related to the over-all control program that absence of control in any one seriously affects the efficiency of the entire operation.

The purpose of this paper is to describe the methods and experiences underlying the industrial waste control program which has been established in the Ford Motor Company and found to be effective. At the present time the Ford Motor Company has in operation nine oil-waste treatment plants, two plating-waste treatment plants, seven assembly plant-waste treatment plants, one combined waste treatment plant (for treatment of steel pickling liquor, plating wastes, and oil wastes), and one underground disposal well. These plants vary greatly in size, ranging all the way from simple batch plants to the 150-cfs rolling mill oil-removal facilities at the Ford Rouge Plant Steel Mills. To be properly functional these plants have required effective organizational and operating control as well as careful design and sound construction.

Organizational Control

In general, the planning, designing, and operating of all Ford waste treatment plants is the responsibility of the Company's Central Staff Plant Engineering Office, although direct control for individual plant operation and maintenance is delegated to the local plants. The Plant Engineering Office provides the specialized knowledge (not usually available on a division or plant level) for obtaining necessary design information, including plant and stream surveys, development of new processes for waste treatment, and over-all control of operations to insure the most effective and economical operation. The waste treatment plants are usually designed either directly by Ford's engineers or by retained consulting or architect-engineering firms. In either case the Plant Engineering Office prepares the reports on all the original process design quantities, the estimated flows, and the treatment requirements. The consulting engineer reviews these and prepares the detailed plant design required to implement the treatment processes.

* Presented at the 31st Annual Meeting, Federation of Sewage and Industrial Wastes Assns.; Detroit, Mich.; Oct. 6–9, 1958.

Sanitary Engineering Laboratory

As part of the Company's industrial waste control program, a special sanitary engineering laboratory is maintained. Here complete chemical, physical, bacteriological, and biological analyses of wastewaters are made, industrial waste surveys are conducted, and research projects are initiated for the purpose of finding more effective industrial waste control methods. This laboratory has been in existence since 1946 and has performed more than 5,000 specialized separate analyses each year. A particularly significant laboratory achievement has been the development of an effective method for soluble oil disinfection. Effective bacteriological control of soluble oil eliminates two of the basic objections to its use by protecting personnel from the dermatitis it frequently engenders and by controlling the typical objectionable odors associated with bacteriological breakdown. This laboratory is registered to use pathogenic organisms for disinfectant testing and all disinfectants used in the Company must be tested, evaluated for performance, and approved here before they may be placed in use. The necessity for the discard of soluble oil for bacteriological reasons has been removed by the use of disinfectants and, in consequence, there has been a significant reduction in waste treatment plant loading.

Reports

Reports from all waste treatment plants are received and compared monthly. Improvements made in one plant are related to performance in plants having similar operations. For example, a monthly report on the three engine plants includes and compares the following items:

1. Volume of waste treated.
2. Total amount of chemical used and cost.
3. Salvaged oil shipped (cost/credit).
4. Total operating costs.
5. Cost of waste treatment per engine produced.

This method of comparison encourages competition and provides a basis for optimum control.

Waste Treatment Plant Planning

Classification

The selection of the proper method for treating the wastes of a new manufacturing or assembly plant is, of course, dictated by the particular type of manufacturing or assembly operations which will be undertaken. At Ford there are three main waste classifications:

1. Assembly plant wastes which include paint spray booth water, caustic chain cleaner water, bonderite metal preparation solutions, and wet sand rub deck solids.
2. Machining plant wastes which include soluble and free oil, metal grinding solids, and emulsion cleaners.
3. Plating plant wastes which include cyanide wastes, acid and metal cleaners, chrome, and other heavy metal solutions.

These wastes are further classified into batch or continuous-discard types and also in terms of the actual quantities anticipated.

The classification of waste products and their economic value must be considered in waste treatment plant planning. Answers must be found to such questions as the following: Is the material lost reclaimable? A product loss? In short natural supply? Strictly a waste product? In the oil waste treatment plants, for example, 3,000 to 50,000 gal of waste oil are recovered each month. This oil contains varying percentages of water and is therefore classified as being suitable only for sale as scrap oil because the cost of refining it for reuse in the manufactur-

ing plants is not economically warranted.

Segregation

Segregating these wastes within the plant and routing them to the proper sewer collection systems is standard practice at Ford and is accomplished through the installation of separate process sewers or cooling towers to avoid hydraulic overload of the waste treatment plant. The importance of segregation and/or conservation of cooling water cannot be overemphasized. For example, at one waste treatment plant, the flow was reduced from 1,200,000 to 400,000 gpd as a result of a conscientious plant survey and subsequent diversion of cooling waters from the process sewer to cooling towers and storm sewers.

Anticipated Quantities

The quantities of the wastes which may be anticipated at the waste treatment plant, always subject to wide variation, are sometimes difficult to establish. It may be stated, however, that any method for estimating wastewater volume on the basis of units of production, or per square foot of building, is unlikely to provide a satisfactory result. Accurate estimation of anticipated quantities is normally accomplished only by careful analysis of the production layout and process equipment and by establishing fixed limitations within which plant layout and production personnel must operate. While this procedure may be regarded by some as an example of the "tail wagging the dog," experience has shown that when each production department or area is specifically limited to a reasonable flow, this limitation will be adhered to more often than not. Conversely, if no limit is set, excessive volumes of process waste at the waste treatment plant can be expected. This type of limitation can be compared to controls which are part of a typical municipal sewer ordinance.

Design and Construction

After the waste volume and concentrations have been established, a specific design is selected for each new treatment plant. Usually the design is one which has been tried at similar Company plants and which operating experiences have shown to be successful. For example, the design of all oil-waste treatment plants is similar in that treatment is accomplished by gravity separation of free oil and chemical precipitation of soluble oil with calcium hydroxide and ferric chloride. Plating waste treatment is accomplished by alkaline chlorination of cyanides and reduction and precipitation of chrome with sulfur dioxide and lime.

Sludge Disposal

Disposal of sludge continues to be a difficult problem, particularly at plants where large areas for lagooning are not available. This problem is most evident with respect to disposal of sludges derived from oil-waste treatment plants and plating plants. These sludges are not particularly amenable to dewatering by vacuum filtration or continued quiescent settling. The most effective method appears to be lagooning in shallow-depth earthen lagoons and air drying. After air drying the sludge can be mechanically handled and trucked to permanent areas for disposal. Recent experiences have shown that this type sludge can be pumped through typical irrigation pipe for some distance. At one location, the sludge from the plating-waste treatment plant was pumped 2,100 ft to a shallow earthen lagoon. After approximately one month of summer drying time, the water had completely evaporated so that the sludge could be moved with bull dozers, loaded, and trucked from the site.

Acidproof Materials

The acidproof materials for concrete and steel tanks and the piping for handling treatment chemicals must be selected with extreme care. Due to tight construction schedules and the adverse weather which frequently prevail during the construction period, optimum conditions for applying acidproof materials to outside tanks are not usually available. Another consideration to be kept in mind is that the material selected should be of a type which can be easily maintained by plant maintenance personnel. Every consideration must also be given to structural design to eliminate so far as possible structural or hairline concrete cracks.

Special Facilities

As an aid to operation, the waste treatment plants are equipped with necessary metering and sampling devices to facilitate continued close control of the operating units. Because of the relatively large number of treatment chemicals used, special consideration must be given to chemical unloading, storage, and application. In plating plants, where large quantities of chlorine are required, rail unloading facilities are furnished to receive tank car load shipments of chlorine. Special facilities are required for handling and storing acid solutions received in carboy lots. Laboratory facilities must be provided within the waste treatment plants for normal operating tests.

Concrete

Although the construction methods and techniques used in the construction of a waste treatment plant are similar to those in use in the general construction trades, special care is required in the placement and finishing of concrete. This is particularly important inasmuch as the concrete must have surfaces which are amenable to waterproofing or acidproofing (or both) and have exposed surfaces which must be smooth to permit proper maintenance.

Operation and Operating Control

Basic Preparations

Certain basic preparations should be completed prior to startup of a new waste treatment plant.

1. The waste treatment supervisor and operators should be selected early and should be given an opportunity to familiarize themselves with all phases of the plant design, construction, and operation. It is particularly important that the waste treatment supervisor be on the site during the construction of the plant. This arrangement permits him to obtain first-hand knowledge of physical details of the plant and to secure the information he needs from the equipment service engineers, including detailed instructions on equipment, operation, and maintenance.

2. All shop drawings, wiring diagrams, and maintenance schedules should be catalogued and located at the waste treatment plant for ready reference.

3. Detailed operating instructions, illustrating the basic features of operation, as well as specifications and quantities of waste treatment chemicals required should be prepared. The operating instructions should include a detailed description of each phase of treatment including methods of control, a flow diagram of the process, and a description of the methods to be used for sampling and analysis. This particular phase of preparation cannot be overemphasized as many waste treatment problems are the result of improper operating control rather than inadequacies in initial design.

Training Program

In cooperation with the Ford Engine and Foundry Division Plant Engineering Department and the Indus-

trial Relations Training Section, a waste treatment plant operators training program has been established and a training manual has been prepared for plants in this Division. On-the-job training programs have been initiated to give waste treatment operators and associated personnel specialized training.

The Waste Treatment Operators Manual is prefaced by the following statement:

> This manual has been prepared for Industrial Waste Treatment Plant Operators and their immediate supervisors. It is a condensation of training material that is presented to those who are engaged in industrial waste treatment and disposal and to others who are directly or indirectly concerned with these activities, such as, laboratory technicians, maintenance workers, and supervisors of these classifications. The basic aim of this manual is to provide proven standard procedures for the sampling, analyzing and treatment of liquid wastes.
>
> Effort has been made to provide information which in conjunction with supplementary class and on-the-job training, will give waste treatment personnel an understanding of the operation of an industrial waste treatment plant. Explanations of specific mechanical details are covered by supervisors on-the-job. The emphasis has been placed primarily on the equipment currently in use, the chemicals used in treating industrial wastes, and general operating procedures.
>
> Additions to and revisions of this text will be made as frequently as may be necessary to provide operating personnel with an up-to-date manual that will be helpful in increasing the effectiveness and efficiency of industrial waste treatment operations. Suggestions and criticisms are invited; each will be studied and evaluated; those having merit will be incorporated when revisions are made.

Within the illustrated manual are chapters with the following titles: Objectives of Program; Code Requirements; The Industrial Waste Treatment System; Chemicals Used and Their Purpose; Operating Procedure; Reporting Procedure; Disposal Procedure for All Liquid Wastes; and Glossary, Abbreviations, Conversion Table, Conversion Factors.

Additional Safeguards

Certain precautions taken within the manufacturing plant will preclude many waste treatment problems. Scrap oil drums, located throughout the plant for disposal of oils removed from machines, reduces the load at the waste treatment plant. Special protection of floor drains or other sewer openings, to exclude paper cups, towels, and mop strings, eliminates trouble with waste treatment plant pumps. The latter problem is all-too-frequently encountered in new plant startup, and the experience of having to deal with flooded production areas due to inoperative waste treatment pumps is a most frightening one.

The proportionate cost of waste treatment should be charged directly to each department profit center within the manufacturing plant. This method of budget control is particularly effective in placing the responsibility for waste treatment plant loadings on the operations which can control them.

Production departments should be required to schedule batch discards during non-production shifts so that the whole treatment process is in accordance with an established plan. In some plants schedules and reasons for discards must be authorized by the plant manager to eliminate batch discards which are unnecessary.

Careful selection of washer and cleaner compounds is necessary in order to keep waste treatment plant loadings at a minimum. Washer and cleaner compounds should be of the non-oil type and should not contain phenol or phenol derivatives. In plants where a large number of industrial washers are used, the oil loadings from oil-type washing compounds can exceed that resulting from lubricating, hydraulic, and soluble-oil losses.

The above are but a few examples of operating control. It is hoped, however, that they have successfully demonstrated that an effective industrial waste control program depends, to very large extent, on continuous and careful operating control.

Summary

An effective industrial waste control program depends on careful organizational control, good planning, and maximum plant operational efforts. Teamwork and cooperation are required between production departments and those responsible for waste treatment. A well-planned and designed waste treatment plant, a staff of well-trained operators, and the type of waste which results from having an informed production operation are the three requisites for optimum industrial waste control.

FRIEL RECEIVES DOCTORATE

Francis S. Friel, President and Treasurer of the consulting engineering firm of Albright and Friel in Philadelphia, is shown receiving an honorary Doctor of Laws degree at Pennsylvania Military College, Chester, Pa., from Lloyd Goman, President of the Board of Trustees.

Mr. Friel, a past President of the Federation, is President of the American Society of Civil Engineers for the current year.

The citation for this degree read in part: "Mr. Friel specializes in sanitation and water power utilization, but the range as well as the number, of civil engineering projects which he has directed is remarkable and indicative of varied interests and vast technical knowledge. He has had responsible association with over 2,065 different civil engineering projects, involving a construction cost exceeding $1.25 billion. He has found time with all this to publish more than 60 articles on engineering works, including a book on standard specifications."

Stream Pollution

EFFECTS OF IMPOUNDMENTS ON DISSOLVED OXYGEN RESOURCES *

By F. W. Kittrell

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When man undertakes to alter nature to make it serve him better he usually accomplishes his major purpose. But in so doing he frequently produces unanticipated results, some of which may not be beneficial and even may be detrimental.

The dams that he builds to impound water for power production, irrigation, flood control, navigation, and other purposes generally accomplish the anticipated benefits. They may also produce auxiliary benefits, such as broad expanses of quiet water suited for recreation, and improved water quality. This discussion deals with one of the undesirable results of impoundment, its effects on dissolved oxygen resources, which in turn may cause decreased pollution assimilation capacity of the water.

The dissolved oxygen problem resulting from impoundment is receiving increasing attention. While a few isolated efforts have been made to resolve the accompanying water use problems, there has been no attempt to overcome the adverse effects on dissolved oxygen at the source in a major reservoir. It is a problem that ultimately must be faced and resolved. Critical situations already have developed in several locations.

* Presented at the 31st Annual Meeting, Federation of Sewage and Industrial Wastes Assns.; Detroit, Mich.; Oct. 6–9, 1958.

Types of Impoundments

The type of the impoundment exerts an important effect on the dissolved oxygen resources of its water. For discussion purposes, reservoirs are separated into two basic types: (a) storage, and (b) main stream reservoirs. Even this simple separation is not absolute. Impoundments with characteristics of storage reservoirs sometimes are located on main streams. Under certain conditions of drawdown and operation, storage reservoirs may perform more like main stream reservoirs.

Storage Reservoir

The typical storage reservoir is located on a tributary stream, which frequently has a steep slope. The dam is high, often being 100 to 125 ft, or more. The stored water spreads well beyond the former river channel into numerous fingers or embayments to form a large surface area. Cross sections of the reservoir are large, in relation to stream flow, and flow velocities are negligible. Water is retained in the reservoir for several months. Passage of water through the reservoir may be discontinuous, and significant portions of the water may remain in storage for nearly a year.

The storage reservoir, as its name implies, is used to store water when surface runoff is high for release when runoff is low. As a result the sur-

face water level varies over a wide range. It generally is highest at or near the end of one rainy season, and lowest before the next rainy season starts. It is not uncommon for the water level to vary 70 to 80 ft, or even more, during the year.

The drawdown of the reservoir requires that the discharge intake be located deep in the reservoir, below the minimum level to which the water will be drawn.

Main Stream Reservoir

The typical main stream impoundment alters the original configuration of the stream much less than the storage reservoir does. The dam is relatively low, rarely exceeding 60 to 80 ft in height, and may be less. Much of the impounded water is restricted to the original channel, though backwater may extend into the valleys of tributary streams to form large embayments in the downstream end of the reservoir. Increase in surface area is small in comparison with that of the storage reservoir. Flow velocities are less than those of the uncontrolled stream, but remain appreciable. Retention of water usually is in the range of a few days to a few weeks, and most of the water is replaced in relatively short periods.

Uses of the main stream reservoir frequently include navigation and production of power. Both of these uses are best served by reasonably constant surface levels. Fluctuations in surface levels usually are controlled within a range of two to three feet.

The relatively constant surface level permits use of discharge intakes that may extend to within 15 to 20 ft of the water surface.

Factors Affecting Reaeration

Even the highest quality natural surface water contains enough organic matter to support biological organisms that use, and tend to deplete, the oxygen dissolved in the water. In the absence of excessive organic matter the tendency to deplete dissolved oxygen in natural streams is balanced by reaeration from the atmosphere. Unpolluted streams usually contain dissolved oxygen at levels near saturation.

As organic pollution increases, reaeration becomes increasingly important in maintaining the dissolved oxygen that is essential to the health of the stream. A stream with high dissolved oxygen and high reaeration capacity is a natural resource that is valuable to adjacent towns and industries that must dispose of treated sewage and organic industrial wastes. A stream with moderate flow and a high reaeration capacity may be a greater asset than one with greater flow but lower reaeration capacity.

Effects of Channel Factors

Consideration of two formulas that have been developed for computing reaeration on the basis of physical characteristics of natural streams indicates the effects of impoundments on reaeration capacity.

Streeter and Phelps (1) derived an empirical formula from data obtained on the Ohio River in 1913 and 1914.

$$k_2 = \frac{cV^n}{H^2} \quad \ldots\ldots\ldots\ldots (1)$$

In this formulation the reaeration coefficient k_2 varies directly as a function of velocity of stream flow V and inversely as the square of the water depth measured to the low water surface elevation H. The velocity factor is modified directly by a coefficient derived from surface slope and channel irregularities c and exponentially by a coefficient derived from relationship of river stage to velocity n.

O'Connor and Dobbins (2) recently have developed a theoretical rather than empirical formula for streams with isotropic flow characteristics.

$$k_2 = \frac{480\ D_L^{0.5}\ s^{0.25}}{H^{1.25}} \quad \ldots\ldots (2)$$

Here the reaeration coefficient varies directly as the square root of the coefficient of molecular diffusion D_L and the fourth root of the stream slope s, and inversely as the 1.25 power of the average depth H.

Both formulas are similar and, in effect, describe turbulence. Neither was developed for application to the impounded waters of reservoirs. However, they illustrate in principle how impoundment affects the reaeration capacity of a stream. Both increased depth and decreased velocity or surface slope of the impounded stream combine to decrease drastically the reaeration capacity below that of the uncontrolled stream.

Thermal Stratification

Neither of the foregoing formulas takes into account the effects of the thermal stratification which occurs in both types of reservoirs. Thermal stratification causes resistance to circulation and mixing of the water and reduces the rate of or even prevents the transport of oxygen absorbed at the surface to the depths of the reservoir.

Each of the two types of reservoirs exhibits its individual type of stratification.

1. Storage reservoir. Stratification of the storage reservoir during summer resembles the classical three strata pattern that is so well known to limnologists from their work on natural lakes. Stratification of natural lakes and its effect on dissolved gases has been studied and reported in great detail in Wisconsin (3) (4) (5). Whipple *et al.* have presented a thorough discussion of numerous factors involved in stratification (6). Hutchinson recently has assembled a tremendous amount of information on natural lakes in his treatise on the subject (7). His descriptions of limnological fundamentals in mathematical terms should appeal particularly to the engineer.

The bulk of the literature on stratification in artificial storage reservoirs and its effect on dissolved gases has been published by Tennessee Valley Authority authors (8) (9) (10) (11) (12) (13) (14) (15) (16) (17) (18).

Thermal stratification in both natural lakes and artificial storage reservoirs is similar in many ways. At the end of the winter season water in the lake or reservoir is cold and has a relatively high density (6). As atmospheric temperature increases, the temperature of both the surface and inflowing waters increases, with a corresponding decrease in density. The difference in density between the top and bottom strata of water ultimately becomes sufficient to prevent wind induced mixing from top to bottom and stratification is established. Summer stratification persists from about April to November in the southern United States, and a month to six weeks less in the northern part of the country.

Between the warm, relatively light surface stratum (epilimnion) and the colder and denser bottom stratum (hypolimnion) there is a third stratum (thermocline) in which the temperature drops abruptly and density increases rapidly from that of the epilimnion to that of the hypolimnion (Figure 1). The thermocline remains in place throughout the six to seven months of summer stratification and acts somewhat like a flexible diaphragm. It separates the epilimnion and hypolimnion and prevents their mixing. A small amount of heat from the sun penetrates to the bottom of the reservoir and produces a small temperature gradient from top to bottom of the hypolimnion. Wind induced mixing usually maintains rather uniform temperature throughout the depth of the epilimnion.

In the southern portion of the country the temperature of the epilimnion may rise as high as 85°F, or even a few degrees higher. The hypolimnion consists of water that was stored dur-

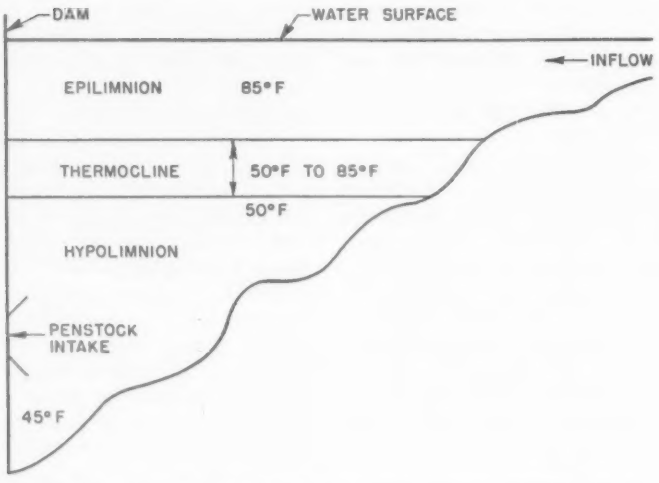

FIGURE 1.—Representative profile showing summer stratification in a typical storage reservoir.

ing winter or early spring. Since stratification excludes the warm atmosphere and much of the sun's heat from the hypolimnion, warming is slight. Even in southern areas the temperature of the hypolimnion may remain as low as 45 to 50°F in some reservoirs.

In the typical large storage reservoir the epilimnion generally is about 30 to 50 ft deep, the thermocline about 10 to 20 ft deep, and the hypolimnion occupies the remainder of the depth to the bottom.

During winter in northern areas a different type of stratification occurs (6). When water temperature drops below 39.2°F (4°C), the density trend is reversed and the water becomes lighter. The denser 39.2°-water sinks to the bottom, while the colder but lighter water in the range between 32.0 and 39.2°F remains on the surface. There are only two strata. The top stratum is quite thin with temperature drop in relation to depth similar to that of the summer thermocline. This condition frequently exists in conjunction with an ice cover.

2. Main stream reservoir. Relatively little is found in the literature regarding stratification of main stream reservoirs.

A peculiar form of summer stratification has been described for Fort Loudon Reservoir on the Tennessee River below Knoxville (19) (20). This involves a thermocline about 50 ft below the water surface at the dam and extending upstream parallel to the bottom of the reservoir until it runs out at the surface about halfway up the reservoir (Figure 2). Above the thermocline is a wedge-shaped epilimnion, with the butt end at the dam. The cooler water from upstream storage reservoirs flowing through Ft. Loudon passes under the thermocline and out through the turbines. This type of stratification has been observed in other main stream reservoirs, though it is not typical of all. It is produced by an inflow of water that is colder than normal surface water of the reservoir.

Another type of stratification has been reported in a few main stream reservoirs. It is suspected, however, that it is more common than the limited

references would indicate. This type of stratification consists of a small but fairly regular temperature gradient of about 5 to 10°F from top to bottom of the reservoir during summer (Figure 2). This gradient is most likely to occur in a reservoir with limited surface area where wind action is moderate and flow velocities are low. In one such reservoir (21), following several hot, clear days, the temperature gradient in the layer of water extending 10 ft below the surface was found to be steep enough to meet the definition of a thermocline (1°C drop per meter of depth).

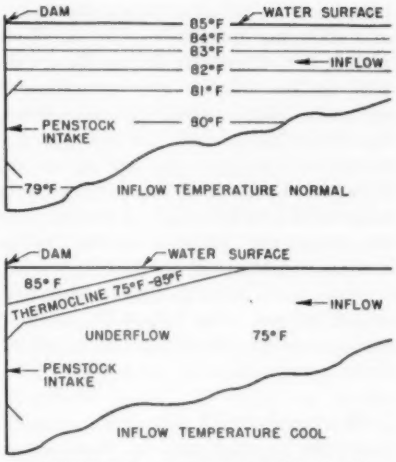

FIGURE 2.—Summer stratification in main stream reservoirs.

Effects on Oxygen Resources

Both the physical changes in configuration of the water mass and the thermal stratification following impoundment reduce reaeration rates of reservoirs to small fractions of those of free flowing streams. The effects of these changes on oxygen resources vary with the type of reservoir.

Storage Reservoir

Although the rate of reaeration in the storage reservoir is drastically reduced, the greatly increased time of water travel through the epilimnion more than compensates for the reduced reaeration. Whereas water may have traveled through the stream section occupied by the reservoir in one to two days before impoundage, it may require months to pass from the upper end of the reservoir to the dam during summer stratification. The time provided usually is adequate for decomposition of excess organic matter. During this period wind-induced currents circulate the water from top to bottom of the epilimnion many times. In addition, the relatively quiet waters encourage increased production of algae, which add oxygen by photosynthesis. As a result water flowing into the epilimnion of a storage reservoir soon approaches saturation with dissolved oxygen. In the Tennessee Valley the sanitary quality, including dissolved oxygen content, of surface layers of large storage reservoirs generally is equal to the best surface water quality found throughout the area (16).

In the hypolimnion, however, the dissolved oxygen content may be quite low. Here the overlying thermocline and epilimnion completely shut off the water of the hypolimnion from contact with the atmosphere. Sufficient sunlight to support photosynthesis does not penetrate to this depth. Oxygen removed from the water by decomposition of organic matter is not replaced. The organic materials in the water when it entered the reservoir, in bottom deposits, and in the bodies of dead plankton settling from the two overlying strata, combine to deplete the dissolved oxygen of the hypolimnion. The detention of water for several months in the hypolimnion may permit total oxygen depletion even in reservoirs with inflow water of good quality.

Examples include Hiwassee Reservoir (16) in North Carolina, which was reported to have negligible municipal and industrial pollution on its watershed. Norris Reservoir (16) in Tennessee had relatively little upstream

pollution. Cherokee Reservoir (16) and Douglas Reservoir (22) in Tennessee and Elephant Butte Reservoir (23) in New Mexico had rather heavy pollution loads on their drainage areas, but those loads were far enough upstream for natural purification to reduce the biochemical oxygen demands to about 1.5 to 3.0 mg/l on entrance to the reservoirs. In spite of the low to moderate pollution in the incoming streams, zero or very nearly zero dissolved oxygen was found in at least portions of the hypolimnions of all of these reservoirs (8) (14) (15) (23) (24).

The absence of dissolved oxygen from the hypolimnions in these reservoirs did not damage the water quality of the epilimnions, which was good to excellent in all cases (16). Before the development of large valves that could be operated under high pressures, penstock intakes were located in the upper levels of older reservoirs and drew water from the oxygen-rich epilimnions. The passage of water through the older stratified artificial reservoirs in summer is similar to that through natural lakes. All flow through and from both is restricted to the surface stratum. Depletion of dissolved oxygen in the hypolimnions caused no dissolved oxygen depletion problems downstream.

The development of large valves that can be operated under high heads permits the installation of penstock intakes deep in modern reservoirs. These deep intakes withdraw water, with little or no dissolved oxygen, from the hypolimnions and discharge it below the dams.

It might be expected that the turbulence of the tailrace below a dam would add important quantities of dissolved oxygen to the water. The time of turbulent contact with the atmosphere is short, however, and dissolved oxygen values as low as 0.8 to 1.0 mg/l have been found below the areas of tailrace turbulence at Cherokee (25) and Douglas (24) Dams.

There is little oxygen demanding material in the waters leaving Cherokee and Douglas dams, and little is introduced between the dams and the confluence of the two streams at Knoxville to form the Tennessee River (16). In spite of the absence of significant oxygen demand in the stream sections involved, recovery of dissolved oxygen is slow. As little as 6 mg/l of dissolved oxygen has been found in the Holston River at its mouth, about 50 miles below Cherokee Dam, and as little as 5 mg/l at the mouth of the French Broad River, about 30 miles below Douglas Dam (24).

The Holston and French Broad Rivers may be defined as moderately turbulent streams. In the turbulent South Fork Holston River below Boone Reservoir, before impoundment of downstream Ft. Patrick Henry Reservoir, the dissolved oxygen increase ranged from as little as 3 mg/l to as much as 8 mg/l in 10.4 miles of stream (17). Variable dissolved oxygen concentrations, such as those cited, are typical of a stream below a storage dam from which discharge rates are regulated to meet the variable requirements of peaking power operation. High discharge rates with deep flow in the stream channel and short times of water travel to downstream points allow a minimum of reaeration. Low discharge rates permit greater reaeration and higher dissolved oxygen concentrations at downstream points.

It is obvious that municipalities and industries discharging wastes to stream sections affected by oxygen depletion in upstream storage reservoirs may be penalized by having to provide treatment in excess of that which would have been necessary on the uncontrolled streams. If the oxygen depleted waters also are intermittently reduced in flow by peaking power operations the penalty can be doubly severe.

The foregoing discussion deals with effects of summer stratification in storage reservoirs. In northern areas where winter stratification occurs, it does not often cause similar problems. The high dissolved oxygen concentration and low rate of oxygen demand of the cold water and the shorter period of winter stratification generally do not result in total oxygen depletion in the bottom stratum during winter. Winter stratification is not common in southern reservoirs.

Main Stream Reservoir

The reaeration characteristics of the main stream reservoir are intermediate between those of the uncontrolled stream and of the epilimnion of the storage reservoir. The main stream reservoir loses much of the reaeration advantages of relatively shallow depth and swift flow of the uncontrolled stream but does not gain the advantages of greatly increased surface area and prolonged detention of the storage reservoir.

With the added deterrent to reaeration of either type of stratification illustrated in Figure 2 it can be surmised that main stream reservoirs may be poor reoxygenation devices. There is some evidence in support of this surmise, though the facts are not yet so well established as they are for storage reservoirs.

During 1936 and 1937 the Tennessee Valley Authority made a year's study of pollution of the Tennessee River (26) below the four major sources of wastes along the 652-mile river. At the start of the study there were only two small reservoirs, Hales Bar and Wilson, on the main river. The two had a total length of 56 miles and a combined storage of 720,000 acre-ft (27). During the study Guntersville Reservoir, with a length of 82 miles and 1,000,000 acre-ft of storage, was filled.

During the year of study dissolved oxygen depletion approaching critical values was found only below Knoxville, at the upper end of the river. Here, in the uncontrolled river, a minimum monthly average dissolved oxygen as low as 4.4 mg/l was found. Twenty-two miles below Knoxville the DO had recovered to 5.0 mg/l. In no other river section was a monthly average of less than 5.5 mg/l found. Most sampling stations yielded 6.0 mg/l dissolved oxygen or more, even in zones below sources of wastes.

Since then the river has been converted to a continuous 630-mile chain of nine reservoirs from Knoxville to Kentucky Dam, 22 miles above the mouth of the river (27). Total storage capacity of the reservoirs is 12,284,600 acre-ft. Minimum stream flows at Chattanooga and downstream have been increased several fold.

Dissolved oxygen determinations are made monthly in the water discharged through the dams. Values as low as 5 mg/l, or slightly less, have been found at several of them. Some of the dams are far removed from significant sources of pollution (24). Pickwick Dam is one example. The closest source of pollution, the Tri-Cities in Alabama, is a minor source 47 miles upstream (26). The closest major source is Chattanooga, 258 miles upstream. Dissolved oxygen values near 5.0 mg/l also have been reported at Kentucky Dam, 182 miles below Pickwick Dam, with no significant pollution entering between the two.

In Ft. Gibson Lake on Grand (Neosho) River in Oklahoma, dissolved oxygen was found to be only 6.0 mg/l, or 67 per cent saturation just above the dam. The water at the dam was estimated to have entered the reservoir with about 1.5 mg/l BOD, and to have been retained in the reservoir about three months.

These limited data suggest that it may not be realistic to expect reaeration in main stream reservoirs to provide important portions of the dis-

solved oxygen needed to stabilize organic wastes.

Examples of Problems

Reports on downstream problems in waste disposal caused by oxygen depletion in reservoirs are limited. There undoubtedly are more problems than have appeared in the literature. They are certain to multiply as water resource development programs produce additional impoundments and as municipal sewered populations and industrial activities expand.

The South Carolina Water Pollution Control Authority has stated that the combination of flow regulated for peaking power operation and low dissolved oxygen content of water discharged from Catawba Reservoir in North Carolina has complicated the problems involved in meeting stream classification standards necessary for protection of existing water uses of the Catawba River in South Carolina (28). Some of the technical details of this problem were reported by Ingols (29). Oxygen depletion at maximum flow just below Catawba Reservoir was computed to be equal to a population equivalent from a town of 1,000,000 people. Recovery of dissolved oxygen in the stream was as little as 0.1 to 0.4 mg/l in 7 miles. Average daily dissolved oxygen values above Rock Hill, South Carolina, where sewage and industrial wastes enter the Catawba, frequently were about 3.0 mg/l. An individual minimum of 1.1 mg/l was reported.

The high reaeration capacity of a turbulent section of South Fork Holston River below Boone Reservoir in Tennessee has already been mentioned (17). Following the study in which those data were obtained, a second dam was built which flooded both the turbulent section and additional open river between Boone Reservoir and the downstream town of Kingsport. The turbines of the new small main stream reservoir, Ft. Patrick Henry, discharge a short distance above Kingsport, where a heavy sewage and industrial waste load enters the river. The impoundment has reduced reaeration in this stretch of river to a minimum. Water with dissolved oxygen content as low as 1 to 2 mg/l now arrives at Kingsport (18). The low dissolved oxygen reaching Kingsport has further complicated an already critical waste disposal problem.

The John H. Kerr Reservoir on Roanoke River in Virginia is a typical storage reservoir, with the usual summer stratification and depletion of oxygen in the hypolimnion (30) (31). In 33 miles of open river between the dam and the upper end of downstream Roanoke Rapids Reservoir the stream at times picks up as little as 2 mg/l of dissolved oxygen. Roanoke Rapids Reservoir has the characteristics of a main stream reservoir, but the intakes to the penstocks of the dam are unusually deep. The cold water from Kerr Reservoir tends to flow through Roanoke Rapids Reservoir at intermediate depths under a surface stratum of warmer water somewhat similar to that found in Fort Loudon Reservoir (32). There was little reaeration in the Roanoke Rapids Reservoir, and downstream water uses, including waste disposal (33) and important commercial fisheries, were threatened. Attempted corrective measures are discussed subsequently.

Grand Lake O' the Cherokees on Grand (Neosho) River in Oklahoma is a storage reservoir with total depletion of oxygen in the hypolimnion (21). In 25 miles of open river between the dam and the upper end of Ft. Gibson Lake the stream may pick up as little as 5 mg/l of dissolved oxygen. Ft. Gibson Lake resembles a main stream reservoir, though it is deeper and has a longer detention period than most of this type. The impoundment of Ft. Gibson Lake has drastically reduced the reaeration capacity of the former

free flowing stream as noted earlier. Sewage from Pryor, Oklahoma, and wastes from nearby industries enter the upper end of the reservoir through Pryor Creek. Both reduced oxygen resources from upstream, caused by storage in Grand Lake O' the Cherokees, and reduced reaeration capacity downstream in Ft. Gibson Lake have complicated the solution of the Pryor waste disposal problem.

Possible Corrective Measures

Numerous methods for correcting the reductions in dissolved oxygen resources caused by impoundments have received consideration. Several methods have been tried either experimentally or in actual practice on small lakes or reservoirs. Additional work is needed to evaluate their possible application to large impoundments.

Multilevel Penstock Intakes

There is little doubt that the downstream dissolved oxygen problems caused by stratified storage reservoirs could be resolved by provision of multilevel penstock intakes. This would permit withdrawal of water from the surface stratum, with its high oxygen content, regardless of the water surface level. Construction costs probably would be high. Other reasons for provision of multilevel intakes to increase benefits to other downstream water uses have been suggested (34).

High Level Penstock Weir

An alternate to the multilevel penstock intake method has been provided at the Roanoke Rapids Reservoir, which has a surface water level fluctuation of only three feet. A weir, with its top about 24 ft below the water surface, has been installed around the penstock intakes to force the water to the surface of the reservoir in the vicinity of the dam and thus to increase reaeration (35). In addition, introduction of air to the penstocks through vacuum breakers has been tried experimentally. These measures have resulted in increased dissolved oxygen in the discharge from Roanoke Rapids Dam most of the time, but dissolved oxygen as low as 3 mg/l has occurred in the discharge as the result of an unusual pattern of stream flow conditions.

Tailrace Design

Special design of the tailrace structure to increase turbulence in the tailrace probably could increase the dissolved oxygen picked up at this point. The increased tailrace turbulence might involve some reduction in efficiency of power production. The short period of turbulent contact with the atmosphere makes it questionable that major additions to dissolved oxygen could be achieved by this method.

Compressed Air Reaeration

Application of air under pressure to the Flambeau River below Pixley Dam in Wisconsin (36) proved rather inefficient in terms of the percentage of applied air that was absorbed by the stream. This method does not appear promising for shallow water streams below dams. Efficiency of air use can be improved by application in the deeper water of the reservoir above the dam. Application at the greater depths, however, increases power requirements for compression of the air.

Compressed air has been used to mix the 75°F epilimnion and 57°F hypolimnion waters and to eliminate stratification in a 103-mil gal, or 315-acre-ft, water supply reservoir at Ossining, New York (37). Air was applied about 7.5 ft below the surface and accomplished sufficient circulation to raise and mix the cold bottom water from a depth of 27 ft. An 8-hp compressor circulated nearly twice the volume of the 80 mil gal of water in the reservoir in 24 hr. The economics of applying this method to a large reservoir with several hundred thousand

acre-feet of storage capacity have not been evaluated.

A unique method of reaerating oxygen deficient hypolimnion water has been in use for several years in the Lausanne, Switzerland, water supply system (38). Lac de Bret serves as the water supply storage basin. Oxygen depletion in the hypolimnion caused solution of iron and resulting difficulties in treatment processes. Water is pumped from the hypolimnion at a depth of about 45 ft, is passed through an aeration chamber, and returned to the same depth from which it is withdrawn, but 600 ft from the pump intake. In one season 10 tons of oxygen were added to 350 mil gal, or 1,080 acre-ft, of water to raise the dissolved oxygen content to 97 per cent of saturation. This was a little over one-fourth of the total lake volume. The aerated water remains at the depth to which it is returned until withdrawn for treatment at the water purification plant. This introduction of oxygen to the level from which water is withdrawn eliminates the necessity for reaerating the entire hypolimnion. It was concluded that the method could be applied with equal success to lakes much larger than the 4,000 acre-ft Lac de Bret.

Introduction of Air to Impoundment Discharge Devices

Air drawn through ducts of flood control tunnels at Fort Randall Dam on the Missouri River in South Dakota (39) resulted in increase of dissolved oxygen from 85 per cent saturation in the reservoir to super-saturation downstream. When flood control tunnels were closed and discharge was restricted to the penstocks, the dissolved oxygen downstream approached that of the reservoir.

The admission of air through vacuum breakers of penstocks at Roanoke Rapids Dam already has been mentioned (35). In that situation the amount of oxygen that could be supplied through the vacuum breakers was limited, and the maximum dissolved oxygen increase was about 2.6 mg/l. This increase could be accomplished only if flow through the penstocks was held to a rate about one-half the normal flow rate. There was an unspecified loss in turbine efficiency.

Similar admission of air to the turbines of Pixley Dam on Flambeau River in Wisconsin has been tried on an experimental basis (40). Special air vents were installed to admit air to the existing turbines. The data obtained indicated that the dissolved oxygen increase fluctuated between 0.16 and 1.57 mg/l. Maximum oxygen absorption efficiency was 37.3 per cent. There were indications that negative pressures in the turbines caused slight decreases in dissolved oxygen when no air was admitted through the ducts. Gross gain in oxygen when air was admitted varied between 0.59 and 4.87 lb/kwhr loss in power production efficiency.

Circulation by Pumping

Stratification was essentially eliminated from West Lost Lake on Pigeon River in Michigan (41) by pumping water from the hypolimnion and returning it to the epilimnion. This small natural lake has a volume of a little more than 3,000,000 cu ft, or about 70 acre-ft. A pump at the edge of the lake drew water with a temperature of 51°F from a depth of 39 ft. The water returned to the surface of the lake near the middle by flowing over the edges of a barge that supported the pump discharge line. This rather crude mixing device was completely effective in mixing the cold hypolimnion water with the 76°F epilimnion water, and no cold water was detected returning to the bottom. Recirculation of about one-fifth of the volume of the lake in 10 days lowered the upper limit of the thermocline from 13 to 25 ft below the surface of

the lake. The mean temperature of the lake did not change significantly, but the epilimnion temperature dropped about 5°F. At the start of pumping, the dissolved oxygen content was about 8.0 mg/l from the surface to a depth of 27 ft. From a depth of 34 ft to the bottom (41 ft) the dissolved oxygen was zero. At the end of pumping the depth of water with 8.0 mg/l of dissolved oxygen had increased to 35 ft and the dissolved oxygen was 2.0 mg/l or more down to 40 ft.

The London Metropolitan Water Board has sponsored research to develop a method of preventing stratification in the proposed 57-ft deep Walton water supply storage reservoir (42). Water will be pumped to storage from the Thames or Lea River. There was concern that stratification might develop in spring when the warmer river water is pumped into the cold water stored in the reservoir. This thermal difference might add to the natural tendency toward stratification resulting from increasing atmospheric temperatures. The research with models was directed toward mixing the inflowing warm water with the colder stored water by jet action. It was determined that the proper number, size, placement, direction, and discharge velocity of the jets could assure mixing of the incoming water and could accomplish complete circulation of all water in the 4-bil gal, or 12,000 acre-ft, reservoir. It was concluded, also, that the jet action could be designed to eliminate any thermal stratification that might form in the reservoir.

Research Needs

Some practical method of preventing or eliminating stratification of large reservoirs should solve a substantial portion of the existing problems of low dissolved oxygen caused by storage impoundments. Two methods of eliminating stratification from small reservoirs have been demonstrated successfully (37) (41). Thus far no one is known to have attempted to translate the experience gained from these small reservoirs to impoundments of several hundred thousand acre-feet capacity. Perhaps the very bulk of the stored water discourages consideration of attempts at controlling the natural phenomenon of stratification in such large reservoirs.

Theoretical Energy Requirements

The useful energy required to mix the water in a reservoir and prevent stratification appears to be surprisingly small. Hutchinson, in his treatise on limnology (7), gives computed values of energy requirements to mix several natural lakes and to keep them mixed throughout an entire period of normal summer stratification. His energy values range between about 1,000 and 25,000 gram-centimeters per square centimeter of lake surface. This is roughly equivalent to 1 to 25 kwhr per acre of lake surface per year.

Several existing reservoirs have surface areas of about 30,000 acres and storage capacities of about 1,500,000 acre-ft. On the basis of Hutchinson's range of values it would require the application of between 30,000 and 750,000 kwhr of useful energy annually to accomplish and maintain mixture of one of these reservoirs. Assuming that hydroelectric power can be produced at the dam for 0.5¢/kwhr, the annual cost of this power would be in the range of $150 to $3,750. The higher value, rather than the lower, probably is more nearly representative for a large reservoir.

Pumping Energy

This small amount of energy would have to be applied to a large quantity of water. Using the hypothetical reservoir cited above, it is possible that the hypolimnion, above the bottom elevation of the penstock intakes, would contain as much as 400,000 acre-ft of

water when stratification becomes established in the spring. Lifting this volume of water into the epilimnion would require a great deal of pumping. The head involved would be almost negligible, possibly not over one foot being needed to overcome density difference and friction. The energy needed for pumping could add another 415,000 kwhr to the power requirements, at a cost of about $2,100.

It should be emphasized that the estimated energy requirements involve only those necessary to lift the water and to overcome its resistance to mixing. The estimates do not include the energy that would be lost in the application of the useful energy. This is an unknown quantity at present.

Pumping Rates and Cost

The large quantity of water involved would have to be pumped in a limited time. Total oxygen depletion of the hypolimnion may occur in a relatively unpolluted reservoir in three to four months after stratification is established. It may be assumed that complete circulation of the water in 60 days would accomplish mixing and prevent excessive oxygen depletion. For the hypothetical reservoir this would require pumpage of 6,700 acre-ft per day, or about 1,500,000 gpm.

An axial flow pump that will deliver 500,000 gpm against 5 ft of head is available for about $40,000. Three of these, at a total cost of $120,000, would pump the water at the required rate. This sum does not include the cost of installation.

Even if the cost of pump installation should equal the purchase price, and the energy requirements should be several times the quantities discussed above, the total cost would not be excessive. It could well be much less than the added cost for waste treatment imposed on a downstream town or industry by reduced dissolved oxygen, caused by impoundment, in the stream to which waste must be discharged.

Practical Research

While the probable costs of pumping to eliminate stratification do not appear excessive, there remains a question of the technical feasibility of eliminating or preventing stratification in a large reservoir by this method. The Public Health Service is engaged in a project intended to resolve this question. During the summer of 1958 weekly observations have been made to determine the natural pattern of temperature and dissolved oxygen stratification in two lakes near Cincinnati.

One of these, Rocky Fork Lake, which is under the jurisdiction of the Ohio Department of Natural Resources, Division of Parks, appears well suited for the purpose. The general shape of this lake resembles that of many storage reservoirs. It is about 40 ft deep at the dam, with a storage capacity of about 34,000 acre-ft, and it has followed a normal stratification pattern during 1958.

The next phase of the study calls for installation of a pump before the start of summer stratification. This will permit observation of the effects of pumping on stratification in a reservoir of medium size.

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DISCUSSION

BY S. LEARY JONES

Executive Secretary, Tennessee Stream Pollution Control Board, Nashville, Tenn.

As discussed by Mr. Kittrell, many impoundments reduce the pollution assimilative capacity of the water. Studies have been made by many investigators to measure these effects on the river water but only limited and isolated efforts have been made to find out how to correct the problem. It is significant that there has been no attempt at the source to overcome the adverse effects on dissolved oxygen in any major reservoir.

A few months ago there was some criticism of the title of this paper because it dealt with an undesirable effect. This criticism is considered unjust and unnecessary. Such criticism is a reminder of the frequently encountered attitude of trying to ignore something that is bad in hopes that it will go away. Low concentrations of dissolved oxygen in the hypolimnion of a reservoir are real and they cannot be ignored. Mr. Kittrell has presented the problem in a fair manner. He points out the many valuable and necessary benefits when dams are built to impound water. He also points out that the water quality is often improved. Many volumes have been written about these benefits and they are real. It is believed that the bene-

ficial effects exceed the undesirable effects, but that is no reason to ignore the bad effects and hope that no one will find out about them.

A reservoir that discharges water with low dissolved oxygen through a dam has the same effect in the area below the dam as any other source of pollution. At Harriman, Tennessee, the undesirable effects occur in a narrow arm of the reservoir, 12 miles from the main reservoir. The pollution, of course, is caused by untreated sewage and paper mill waste but a combination of reduced reaeration, thermal stratification, low stream flow, and density currents causes a serious problem at the public water supply intake about two miles upstream. Studies in this Emory River Arm of the reservoir indicated that the assimilative capacity of the water was so low that the only hope to correct the problem was to pipe the effluent to the main reservoir after primary treatment.

Another type of problem has occurred at Bristol, Tennessee, which obtains its source of water from the South Holston River a short distance below a dam. At times water from the hypolimnion of the reservoir contains high concentrations of iron and manganese. This situation makes it unfortunate that the water is not obtained upstream from the dam and from multiple intakes.

Mr. Kittrell discusses the problem at Kingsport, Tennessee, where the 3 to 8 mg/l of dissolved oxygen increase in the 10.4 miles below Boone Dam was reduced substantially by Ft. Patrick Henry Reservoir, and water with only 1 to 2 mg/l of DO now arrives at Kingsport. Combined with this lack of oxygen is the variable stream flow which is caused by power peaking operations at the upstream dam. It is difficult to calculate the oxygen sag curve in this stretch of river and even more difficult to calculate assimilative capacity of the stream.

The section of Mr. Kittrell's paper on possible corrective measures and the work that has been done is particularly pertinent. Much research is needed and perhaps this paper will be instrumental in starting some of this work.

DISCUSSION

By Robert S. Ingols

Professor and Head, Department of Applied Biology, Georgia Institute of Technology, Atlanta, Ga.

Congratulations are due Mr. Kittrell for an excellent presentation of an important subject. In the introductory comments of this paper the statement is made that the problem being discussed is that of a reduction in the quantity of pollution that a river below a power impoundment can assimilate. Thus it is implied that the discussion is not about pollution, only about something that interferes with pollution absorption because pollution can result only from the addition of something. If the downstream users are damaged as a result of the use of the water for power generation, why is not this damage pollution? At least, it is so defined in law in Georgia.

In South Carolina, however, a water is graded as fit for human consumption after complete treatment if it contains initially less than a certain number of bacteria and if it possesses at least 4 mg/l dissolved oxygen. When, however, a city is located close to the discharge of a power impoundment the river water may meet all other quality criteria to a very high degree yet fail

completely to meet the requirement for dissolved oxygen. Of course, this water is considered highly desirable for potable purposes and is so used.

However, when the discharge from this same city enters the river, where the dissolved oxygen values are extremely low, the code of the State Water Pollution Control Board demands that the quality of water at the sagpoint shall have more than the minimum dissolved oxygen required for the river of that classification, namely 4 mg/l. This requirement is made in spite of the fact that the distance may not be great enough for reaeration alone to raise the dissolved oxygen of the river water itself to the acceptable minimum. Thus, it is seen that damage can be inflicted by inflexible codes of water authorities drawn up primarily to meet a concept which defines pollution as something that is added to a water while relieving other users of any responsibility, because they may not be directly responsible for killing fish. Thus, the problem is not only one of the inability of the stream below a power impoundment to assimilate pollution without killing fish, but also the difficulty of using the results of the dissolved oxygen test as a criterion of correct or acceptable water quality in a polluted stream.

Because of the extremely high scour of a power impoundment discharge for maximum power generation (peaking operation), the dissolved oxygen drops rapidly in a zone of pollution by organic matter because the slime which collects on the stones during low flow is removed during the peak flow. During the power surge it has been observed that in a DO sample bottle organisms collect to an extent of approximately ⅙ of the total volume of the bottle. This mass of inoculum can make a significant difference in the rate of dissolved oxygen drop where the stream already lacks the required minimum dissolved oxygen value for acceptance under a water pollution authority code. This raises the question, "How can dissolved oxygen be used as the most important criterion for acceptable water quality in an area where the water is a result of the discharge from a power impoundment?"

Where observations of water discharged from impoundments have been made (19) (20) (21) (24) (26) (27), low dissolved oxygen values have been observed and it is usual to find low temperatures. These temperatures are reported at approximately 10 to 15°C while the dissolved oxygen may be anywhere from 0 to 50 per cent of saturation depending on the age of the reservoir, the time of the year, and the temperature of the water during the winter season. However, it may occur that the temperature of the river or the water from the power impoundment may approach that of normal river water from 25 to 35°C. Thus, the Catawba River in South Carolina receives impounded water with dissolved oxygen at 10 to 50 per cent of the saturation value with temperatures of 25 to 30°C from the dam. While this observation has been made over the past several years at Rock Hill, the lack of the usual correlation was not fully grasped. Recently it was realized that it was unusual but it has not been possible to obtain enough information to permit an interpretation of the lack of correlation. In this river, therefore, the water is not only low in dissolved oxygen but high in temperature and the rates of biological oxygen demand of the river are exceedingly high during the summer months, producing a sagpoint within three miles.

While many reservoirs have been known to improve in the quality of water that discharges from the power impoundment from year to year, other reservoirs are known to have periods during several years where good quality water comes from the power im-

poundment while during other years the water is very poor in quality. This phenomenon may be related to the dry years; the driest years have generally been followed by the water of poorest quality during the next summer. Just what is the mechanism of this is not known specifically because observations of the specific reservoirs known to vary have not been made during a dry year, but adjacent reservoirs have been observed where lush plant growths have occurred on the exposed mud flats during a dry year. These can then be submerged when the power pool reaches its maximum level and contribute the organic matter to rapidly deteriorate the water quality for the summer after the dry year. Again the quality of the water may be periodic or it may be of a continually improving nature but this is a problem that must be studied at an individual reservoir rather than on a general basis.

MEETINGS OF INTEREST

Sept. 13–18 **American Chemical Society,** 136th National Meeting, Atlantic City, N. J. H. B. Gustafson, P. O. Box 5033, Tucson, Ariz.

Sept. 14–19 **Symposium on the Treatment of Waste Waters,** Kings College, Newcastle upon Tyne, University of Durham, England. Peter C. G. Isaac, Public Health Engineering Section, Dept. of Civil Engineering, Kings College, Newcastle upon Tyne, England.

Sept. 17–18 **Illinois Association of Sanitary Districts,** Peoria, Ill. R. E. Anderson, Secretary, North Shore Sanitary District, Dahringer Road, Waukegan, Ill.

Sept. 20–23 **American Public Works Association,** Olympic Hotel, Seattle, Wash. Robert D. Bugher, Executive Director, 1313 E. 60th Street, Chicago 37, Ill.

Sept. 21–25 **14th Annual Instrument-Automation Conference and Exhibit,** Instrument Society of America, International Amphitheater, Chicago, Ill. H. S. Kindler, Director of Tech. and Educational Services, 313 6th Avenue, Pittsburgh 22, Pa.

Sept. 27–30 **American Institute of Chemical Engineers,** St. Paul Hotel, St. Paul, Minn. F. J. Van Antwerpen, Secretary, 25 W. 45th Street, New York 36, N. Y.

Oct. 10 **Conference of Wisconsin Sewage Works Operators,** Kenosha, Wis. C. W. Bogenhagen, Secretary-Treasurer, 313 Fifteenth Street, Fond du Lac, Wis.

Oct. 11–16 **American Society for Testing Materials,** Sheraton-Palace Hotel, San Francisco, Calif. ASTM, 1916 Race Street, Philadelphia 3, Pa.

Oct. 19–23 **American Public Health Association,** Annual Meeting, Convention Hall, Atlantic City, N. J. Dr. Berwyn F. Mattison, Executive Secretary, APHA, 1790 Broadway, New York, N. Y.

Oct. 19–23 **American Society of Civil Engineers,** Annual Convention, Hotel Statler, Washington, D. C. W. H. Wisely, Executive Secretary, ASCE, 33 W. 39th Street, New York 18, N. Y.

Oct. 20–22 **National Conference on Standards,** American Standards Association, Sheraton-Cadillac Hotel, Detroit, Mich.

THE OPERATOR'S CORNER

GENERATION AND CONTROL OF SULFIDE IN FILLED PIPES

By Richard Pomeroy

Pomeroy and Associates, Pasadena, Calif.

AMOUNT OF SULFIDE GENERATED

The "Progress Report on Sulfide Control Research" (1) published in 1946, set forth the principle that sulfide production in a sewer occurs on the walls of the pipe. In ordinary free-flowing sewers there is no generation in the body of the stream; rather, the oxygen continually being absorbed at the surface destroys part or all of the sulfide coming from the walls. The opinion was expressed that even in completely filled pipes the amount produced in the body of the stream is generally negligible. Viehl came to this conclusion independently, referring to the source of sulfide as the "sielhaut," or sewer skin (2).

Development of Equations

It was proposed in the 1946 report (1) that the amount of sulfide produced on the surface is proportional to the surface area available to support sulfide-producing slimes, and to the "effective BOD," which is the 5-day BOD at 20°C multiplied by the temperature function, $1.07(T-20)$, in which T is the sewage temperature in °C. Expressed mathematically:

$$S_w = MAC_{EBOD} \quad \ldots\ldots (1)$$

in which

S_w = weight of sulfide produced on the wall, lb/day;
M = coefficient, lb/day/sq ft/mg per liter;
A = area of pipe wall, sq ft; and
C_{EBOD} = effective *BOD*, mg/l.

No data were published, but it was stated, in effect, that from the information available it appeared that M had a numerical value somewhere between 3×10^{-6} and 6×10^{-6}.

In very large pipes (especially long, large pipes) where the sewage has time to become thoroughly anaerobic and well seeded, the amount of sulfide produced in the stream may be a substantial amount in comparison with the amount produced on the walls. Assuming that the amount produced is proportional to the volume of the pipe and to the effective BOD, C_{EBOD}, one may write:

$$S_S = NVC_{EBOD} \quad \ldots\ldots (2)$$

in which

S_S = weight of sulfide produced in the sewage stream, lb/day;
N = coefficient, lb/day/cu ft/mg per liter; and
V = volume of sewage in pipe, cu ft.

For circular pipes, Equations 1 and 2 may be written:

$$S_w = M\pi DLC_{EBOD} \quad \ldots\ldots (3)$$

where D is the pipe diameter in ft and L is the length of the filled pipe in ft; and

$$S_S = N\frac{\pi D^2 L}{4}C_{EBOD} \quad \ldots\ldots (4)$$

By addition, total sulfide production, S_T, may then be expressed as:

$$S_T = C_{EBOD}\pi DL\left(M + \frac{ND}{4}\right) \quad \ldots (5)$$

Substituting P for $N/4M$, Equation 5 becomes

$$S_T = MC_{EBOD}\pi DL(1 + PD) \quad \ldots (6)$$

For calculating the increase in concentration of sulfide in sewage going through a force main, the following equation may be used:

$$\Delta C_S = \frac{44.6MtC_{EBOD}}{D}(1 + PD) \quad \ldots (7)$$

where C_S is concentration of sulfide in mg/l and t is the time of passage in minutes.

Since pipe diameters are usually expressed in inches in countries using the English system, Equation 7 is conveniently written:

$$\Delta C_S = \frac{535MtC_{EBOD}}{d}\left(1 + \frac{Pd}{12}\right) \quad \ldots (8)$$

Theoretically, M and P could be determined with simultaneous equations on pairs of lines of different diameters. However, there were only two long, large-diameter sewers among the lines investigated, thus evaluation of M and P in a theoretical fashion was prevented. One of these lines is the Spotswood main at Melbourne, Australia. Data for this line are the most reliable available and they indicate that the value of P is 0.09. However, the probable existence of a lag phase, as explained later, would affect this value. The other large line is really the tunnel network of the Los Angeles County Sanitation Districts. Here P-values of 0.08 and 0.12 have been measured, and the latter is considered more accurate. Because the behavior of filled sewers is complicated by other factors anyway, evaluation of M and P is initiated by estimating a value for P in Equation 8.

In comparing the Spotswood main and the Los Angeles County Sanitation Districts' tunnels with smaller lines in which long detention time and other factors are favorable for maximum sulfide production, it appears that the value of P should be about 0.12. This corresponds to production of about 0.4 mg/l of sulfide per hr in the body of the stream, which is a little more than half of the total amount produced in the tunnels. This is within the range (0.2 to 0.5 mg/l) to be expected from bottle experiments in which sewage of average strength is thoroughly anaerobic and well seeded.

Introducing this value of P, and using K in place of $535M$, gives

$$\Delta C_S = KtC_{EBOD}\frac{(1 + 0.01d)}{d} \quad \ldots (9)$$

If the pipe is of other than circular cross section, d may be taken as the diameter of an equivalent pipe having the same ratio of perimeter to cross section; it is four times the hydraulic radius. If a force main is made up of a sequence of pipes of different diameters, d is a complex function of the diameters. The arithmetic average diameter may be used unless there is a large disparity in the sizes, in which case calculations should be made separately for each section.

Application of Equations

It has been apparent from the first that the simple concepts implied by these equations are applicable only within certain limits. In the 1946 report (1), it was pointed out that the force main in North Long Beach, Calif., did not show any sulfide build-up when the BOD was less than about 50 mg/l. This was explained by the

fact that if sewage is weak and the temperature low, a significant amount of dissolved oxygen generally will be carried into the force main with the sewage. No sulfide buildup can occur until this oxygen is used up; and with weak sewage, depletion of the oxygen may not occur during the time of passage through the main.

Lag Phase

The existence of a lag phase, hypothesized in the case of the North Long Beach force main, is demonstrated in two cases where tests have been made at sampling points along the line. In the first case, W. J. Davy, of Melbourne, Australia, reported on a main which showed almost no generation for 5,000 ft (about 40 min), and then a substantial rate of generation for the next 6,000 ft. In the second case, tests at Oceanside, Calif., showed a fairly low rate of generation for 3,000 ft, increasing to a high rate somewhere between there and 8,000 ft.

If the lag phase could be predicted, one would be helped in making predictions of the amount of sulfide that would be produced in a filled sewer. Unfortunately, because of the many factors involved there does not seem to be any practical way to do this. Tests may be made for dissolved oxygen in sewage entering a force main, and the amount would give some idea of the expected lag. But on the other hand, for example, after the sewage leaves the wet well some air may get into the flow through leaks on the suction side of the pump. Also, where the nitrate content of a water supply is high, the lag phase may be extended.

In view of these complicating factors it seems best not to attempt to analyze the lag phase. Without correcting for the lag phase, Equation 9 will not be reliable for predicting just how much sulfide will be formed, but by interpretation, constants can be selected which will represent conditions where the lag phase apparently has little or no effect. The resulting equation will then provide a means for estimating the maximum amount of sulfide that could be generated.

Certain other effects may also reduce sulfide generation below the level that may be reached in lines free from retarding influences. One of these is the possibility of a depressed condition of the slimes. Sulfide generation is controlled in a number of places by massive dosages of slime-killing chemicals. It generally takes from a week to a month for sulfide generation to return to normal after one of these shock treatments. Another possibility is that sulfates or organic nutrients become depleted. However, this would happen only after a long detention time, and only after the sulfide production had already reached a high level.

The question has been raised as to whether high velocities may reduce the slime accumulation and hence the rate of sulfide generation. In a case where there was a thick slime accumulation, flushing resulted in a temporary reduction of sulfide production. But in a force main where the normal velocity was 3.5 fps, this velocity did not seem to keep the pipe clean enough to make any difference in sulfide levels, and sulfide generation was no less than in lines with low velocities. Velocity undoubtedly has some effect, but in filled pipes it appears to be a minor mitigating factor when it is below 4 fps.

Evaluating K

Tests were made on suitable pressure sewers for the purpose of finding values of K in Equation 9 and the results are shown in Table I. The Australian data were generously furnished by Mr. D. K. B. Thistlethwayte, Metropolitan Water, Sewage and Drainage Board, Sydney, and Messrs. E. F. Borrie and W. J. Davy, Melbourne and Metropolitan Board of Works, Melbourne. Determinations were made of BOD, temperature, detention time, and

entrance and exit sulfide concentrations. The Australian results are generally averages of tests made on from 2 to 5 days, the other tests were, in most cases, run over periods of from 1 to 4 hr, with 6 to 40 sulfide analyses made at each end of the line for each test. Some lines were tested two or three times. Repetitive tests are sometimes averaged, but if a summer test gave a higher K value than a winter test (as is often the case because of relatively shorter lag in the summer), the summer results are recorded in Table I. Selection of data to this extent is practiced because the aim is to show how much sulfide may be produced under adverse conditions. Table I includes some pressure lines for which only partial data are available, or for which data on the different variables were taken at different times.

Attempts were made to find as many lines as possible which are heavy sulfide producers. Many more lines could be found, especially short ones, in which sulfide buildup is zero.

Because of erratic fluctuations of sewage strength and sulfide concentrations, and the problems involved in determining the various parameters, it is considered that the "probable error" of a single K value in Table I, as compared with an infinite series of tests under the same conditions and with perfect data, is ± 20 per cent. However, the probable error is calculated to be as low as ± 5 per cent for the best Australian data.

Discussion

Two of the lines tested have K values much higher than the others. Both of these are cast iron lines carrying sewages which contain considerable amounts of sea water and there is a possibility that they may suffer anaerobic corrosion under these conditions.

The Mission Bay line at San Diego, Calif., has a coefficient of roughness n of 0.037 as calculated from the Manning formula. Volumetric measurements, however, indicated that the pipe is 20 per cent occluded. If n is re-calculated on the basis of a reduced volume it has a value of 0.027, which is still very high, indicating a very rough interior. Later, the city of San Diego cut the pipe and found that substantial corrosion is in progress. Information is not available as to the condition of the other line (Norfolk, Worth St.) with the high K value.

If bacterial corrosion of the iron is in progress, the sulfide output of the main could increase. Yet, the apparent excess of sulfide output is more than can be accounted for by the amount of iron being dissolved. Nevertheless, a synergistic effect cannot be ruled out. Other cases are known in which anaerobic corrosion is rapid in the presence of sea water. A case at the Terminal Island plant of the city of Los Angeles was reported by Parkes (3).

The high sulfate concentrations due to the inclusion of sea water in the sewage may be considered as a factor in the rate of sulfide generation in these non-typical cases, but it probably is not an important one. At the time of one of the tests, the Mission Bay line was carrying sewage with a sea water content of about 13 per cent, as judged by its chloride content. The sulfate concentration was presumably about 190 mg/l higher than the water supply. Still, even this concentration can be found in other sewages which do not show abnormal sulfide generation. This, and the lack of published evidence showing that the sulfate concentration significantly affects the rate of sulfide generation, are indications that sulfate concentration in these cases probably is not an important factor except as it may be an influence in bacterial corrosion of the iron. The high chloride concentration, which is a strong accelerator of corrosion reactions, is believed to be an important factor.

TABLE I.—Data on Sulfide Buildup in Filled Sewers

Item No.	Force Main Location and Designation	Diam. (in.)	Length (ft)	Flow (cfs)	Detention (min)	Infl. Sulfide (mg/l)	Effl. Sulfide (mg/l)	Sulfide Increase (mg/l)	BOD (mg/l)	Temp. (°C)	Effective BOD	K in Eq. 9
	Australia:											
1.	Melbourne, Spotswood Rising Main	72	14,750	103–120	73–110	0.48–2.88	2.05–6.50	1.57–4.41	361–724	16–22	268–789	.00235
2.	Sidney, Middle Harbour Siphon	72	1,075	33.8	15	1.57	1.90	0.33	510	19	477	.00193
3.	Sidney, Mascot Siphon*	78	1,064	98.2	12	0.59	0.77	0.18	429	20	429	.00153
4.	Sidney, Manly Lagoon Siphon*	18	1,170	4.33	16	0.20†	0.28	0.08	280	22	320	.00024
5.	Sidney, Pump Sta. 42	8	2,460	1.20	12	0.70†	0.70	0	170	24	225	0
6.	Sidney, Pump Sta. 46	6	960	0.85	3.7	0.08†	0.15	0.07	230	22	263	.00040
7.	Sidney, Pump Sta. 67	30	6,300	136	38	0.19†	0.45	0.26	430	24	560	.00028
8.	Sidney, Pump Sta. 91	18	4,160	4.4	28	0.04†	0.05	0.01	700	25	980	.00001
9.	Sidney, Pump Sta. 99	12	1,248	3.12	5.2	0.07†	0.20	0.13	193	23	237	.00113
10.	Sidney, Pump Sta. 175	20	4,000	0.97	150	0.21	1.67	1.46	210	15.5	155	.00105
	California:											
11.	Santa Barbara, Airport	8	9,300	0.13	406	1.50	11.2	9.7	198	20	198	.00089
12.	Santa Barbara, State University	8	3,100	0.14	125	0.05	3.97	3.91	111	21.4	122	.00191
13.	Pasadena, Pomeroy & Assoc.	0.34	19.6	5.9×10^{-4}	34	0.4	8.7	8.3	116	22	132	.00062
14.	Los Angeles, Venice	30 36	1,000 7,120	29.2	31.5	0.41	1.10	0.69	188	25.8	278	.00204
15.	Los Angeles, 74th and Airport*	10	3,510	1.80	36	0.30	2.52	2.22	237	28.6	424	.00132
16.	Los Angeles, Centinella Siphon‡	78	1,860	396	7.9	0.76	0.81	0.05	263	26.8	416	.00067
17.	Los Angeles, Manchester Pump Sta.	16	2,590	5.25	11.5	0.39	0.46	0.07	251	22.3	293	.00029
18.	Los Angeles Co., Joint Outfall Sewer "C"	54	9,646	55.5	46	0.46	1.10	0.64	296	24.6	404	.00121
19.	Los Angeles Co., Tunnels	96&144	55,960	342	220	0.81	3.56	2.75	222	22.5	263	.00258
20.	Long Beach, Alamitos Bay	10	4,200	0.24	163	0.3	15.1	14.8	258	22.3	308	.00268
21.	Long Beach, Naples	12	2,689	0.73	48	0.77	2.96	2.19	271	25.1	382	.00128
22.	Long Beach, Belmont Park	8	1,254	0.30	24	0.10	1.15	1.05	200	24.0	262	.00124
23.	Long Beach, North Long Beach	21	4,300	1.44	120	—	—	2.40	—	—	150	.00231§
24.	Orange Co., Garden Grove Trask	8	3,929	0.31	73	0.63	4.30	3.67	237	23.6	303	.00123
25.	Orange Co., Garden Grove Lampson	8	3,824	0.49	45	0.92	5.34	4.39	265	25.0	372	.00194
26.	Orange Co., Midway City No. 1	12	4,960	2.9	22.5	1.85	2.43	0.58	315	24.2	418	.00066
27.	Orange Co., Midway City No. 3	8	1,965	0.76	16.8	1.30	2.24	0.94	278	24.2	370	.00112
28.	Orange Co., Fullerton	16&18	10,600	4.0	70	0.5	8.5	8.0	500¶	22.8	600¶	.00277
29.	Orange Co., Rossmore	6	10,000	0.78	420	1	20	19	235	24.0	308	.00083
30.	Orange Co., Marine Air Base	8	5,018	0.22	131	0.7	11.0	10.3	252	22.9	306	.00190
31.	Orange Co., South Laguna	12	5,428	0.38	192	0.5	11.6	11.1	237	19.1	222	.00278
32.	Oceanside, Reclamation Main	24	8,245	3.28	203	3.5	10.4	6.9	250	20	250	.00263
33.	San Diego, Mission Bay	14 12	1,367 2,684	0.86	69.2	2.43	9.96	7.53	189	20.1	191	.00642
	Virginia:											
34.	Norfolk, Roland Park No. 33	12	2,800	0.52	70	0.05	2.28	2.23	198	23.0	242	.00141
35.	Norfolk, Balview No. 17	10	3,740	0.47	72	1.53	6.73	5.2	210	23.3	262	.00250
36.	Norfolk, Worth St. No. 22	10	7,600	0.45	153	2.00	15.1	13.1	125	22.7	150	.00518
37.	Norfolk, Forest Park No. 47	8	4,945	0.24	119	0.10	5.47	5.4	266	28.0	457	.00074
38.	Hampton Rd. San. Dist., Ingleside	8	3,500	0.21	98	0.62	3.17	2.55	109	23.5	138	.00141
39.	Hampton Rd. San. Dist., Norview No. 49A	8	1,810	0.32	33	0.33	1.14	0.81	262	22.2	304	.00060
40.	So. Norfolk, No. 3 and No. 56A	18 20	427 7,171	1.45	181	0.44	4.94	4.5	300	22.9	365	.00113
41.	Norfolk Co., Plymouth Park	8 12	4,800 780	0.18	213	0.05	2.06	2.01	153	22.8	165	.00045
	Miscellaneous:											
42.	Las Vegas, Nev.	10	3,200	0.22	131	4.1	15.6	11.5	236	21.5	268	.00298
43.	Bismarck, N. Dak.	20	3,500	0.35	360	0.9	10.0	9.1	—	12	—	—
44.	Leipzig, Germany	43	42,600	30	240	—	—	2 to 10	280	16.2	221	—

* Two identical mains. † DO found in influent. ‡ Three identical mains. § Computed from data in Ref. 1. ¶ Data from different sources.

The significance of the results, other than those for the two abnormal cases, may be summarized as follows:

1. Up to a detention time of 10 min, very little sulfide is produced in any of the lines. In two of the rising mains in Sydney, Australia, with detention times of 3.7 and 5.2 min, buildups of 0.07 and 0.13 mg/l are shown. In Los Angeles, Calif., the Centinella Siphon, with a detention time of 7.9 min, experienced an average buildup over a 3.5-hr period of 0.05 mg/l. For the first two hours, however, the buildup was 0.22 mg/l, which is as much as would be expected with no lag. Later on there was a decline instead of a buildup, resulting in a low average buildup.

If any sulfide is produced in a line with a detention time less than 10 min, the amount is not likely to exceed an amount calculated by setting K equal to 0.0010 in Equation 9.

2. Between 10 and 60 min, larger amounts of sulfide must be expected. On the basis of 17 results, it appears that the amount is not likely to exceed the amount calculated by using a K value of 0.0020.

3. For detention times between 1 and 5 hr, the lag phase has relatively little effect. Along with the results from lines in this detention range are placed the results from the two lines in which the effect of the lag phase presumably has been eliminated—North Long Beach and Oceanside. Of the 19 results (excluding the two abnormally high ones) in this group, nine K values are above 0.0020. Of these nine, one is based on uncertain data, and another is the result from the large line used to estimate P, wherefore, it is not properly used in the determination of M. The other seven results constitute a group, all within the range of probable error, giving an average K value of 0.0026. This may be considered as indicative of the rate of output of sulfide to be expected when conditions are conducive to sulfide generation.

4. For making predictions at deten-

TABLE II.—Comparison of Predicted and Observed Sulfide Buildup in Force Mains

Item No. (from Table I)	Sulfide Buildup (mg/l)		Obser. Pred. (%)
	Predicted Maximum	Observed	
1	3.63	3.19	89
2	0.44	0.33	75
3	0.30	0.18	60
4	0.87	0.08	9
5	0.95	0	0
6	0.45	0.07	16
7	2.40	0.26	11
8	4.68	0.01	0
9	0.30	0.13	43
10	3.63	1.46	40
11	28.2	9.7	34
12	5.35	3.92	73
13	34.4	8.3	24
14	0.87	0.69	79
15	4.37	2.22	51
16	0.19	0.05	26
17	0.64	0.07	11
18	1.38	0.64	46
19	2.76	2.75	100
20	14.4	14.8	103
21	4.45	2.19	49
22	2.21	1.05	48
23	2.70	2.40	89
24	7.76	3.67	47
25	5.58	4.39	78
26	2.28	0.58	25
27	2.19	0.94	43
28	7.52	8.0	106
29	59.4	19	32
30	14.1	10.3	73
31	10.4	11.1	107
32	6.82	6.9	101
33	3.07	7.53	245
34	4.12	2.23	54
35	5.40	5.2	96
36	6.56	13.1	200
37	19.1	5.4	28
38	4.75	2.55	54
39	3.52	0.81	23
40	10.37	4.5	43
41	11.6	2.01	17
42	10.0	11.5	115
44	4.6	2–10	—

tion times greater than 5 hr, it would be well to use the K value used for the 1- to 5-hr group, bearing in mind that exhaustion of nutrients, or of the most readily available nutrients, may limit sulfide production. Any calculation showing a predicted concentration greater than 15 mg/l should be considered to be "15 +." The two force mains tested in which the detention time exceeded 5 hr show low apparent K values. Exhaustion of nutrients was a factor in at least the one case where the actual buildup was 19 mg/l and the calculated buildup was 56 mg/l.

5. Sulfide generation at least twice as great as appears normal for other lines was found in the case of two cast iron lines carrying sewage with a considerable admixture of sea water. It is believed that anaerobic corrosion of the iron in these cases is at least a partial explanation.

Assuming a value of 0.0026 for K, the value of M is 4.85×10^{-6}, or, say, 5×10^{-6}. This is in pounds of sulfide per day per square foot per mg/l of effective BOD.

A comparison of observed and computed sulfide buildups is found in Table II. The K value selected for introduction into Equation 9 was 0.0026. Most of the lines produced less sulfide than predicted since the equation applies only to the minority of cases where all conditions are favorable for sulfide generation.

SULFIDE CONTROL BY AIR INJECTION

High concentrations of sulfide must be expected from any force main or filled sewer in which sewage is retained for some hours, and substantial amounts may be produced in a half hour or less in small pipes.

In the design of a sewerage system, the engineer usually tries to keep force mains and siphons to a minimum. Yet such structures are necessary in many situations. Even where there is an alternate design, the alternative

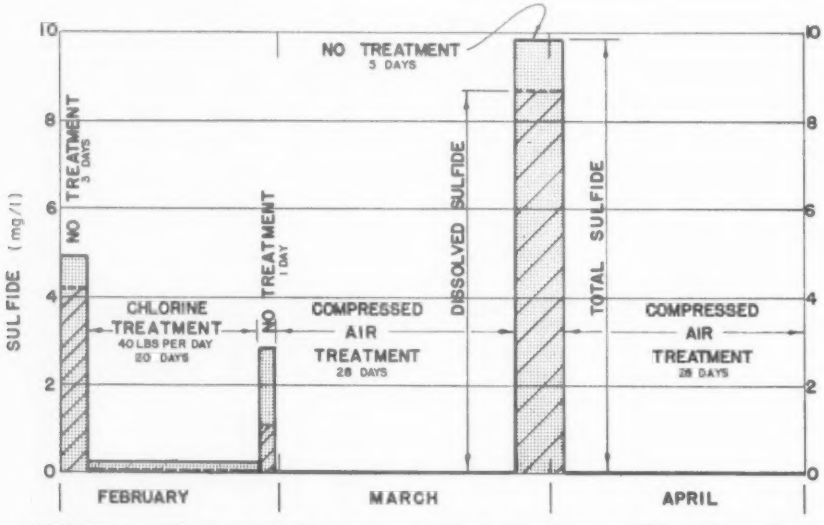

FIGURE 1.—Effects of chlorine treatment and air injection on sulfide buildup, Buena Park force main, Orange County, Calif. Reproduced with permission of the Orange County Joint Outfall Sewer.

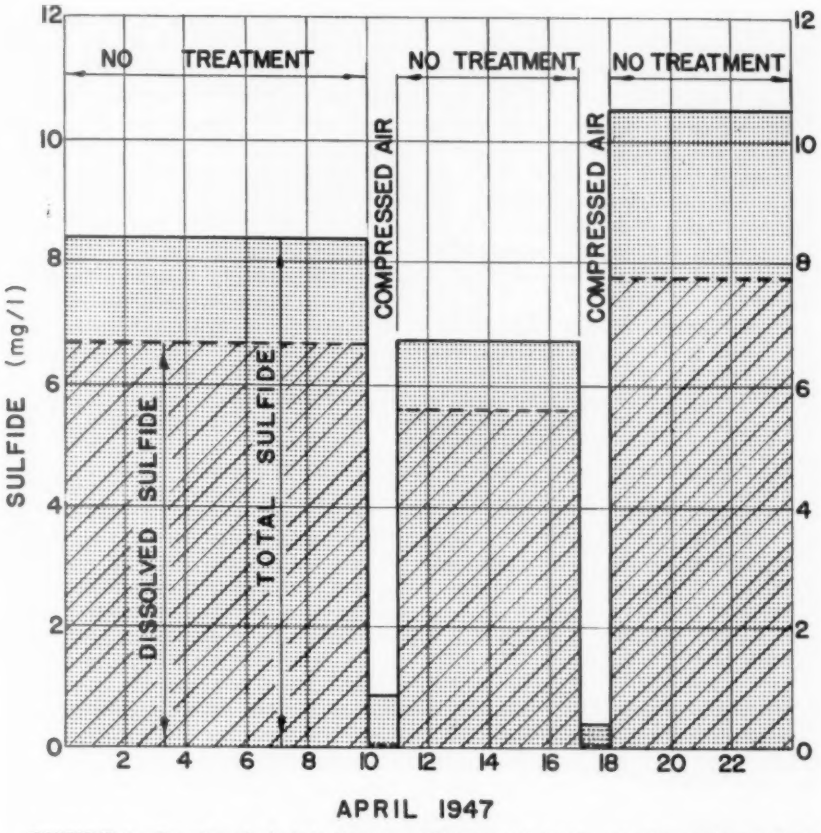

FIGURE 2.—Results of air injection in sulfide-control treatment, Orangethorpe force main, Orange County, Calif. Reproduced with permission of the Orange County Joint Outfall Sewer.

may be costly. Thus if a suitable method for sulfide control is available, the use of a long force main may be satisfactory and economical.

There are several practical methods of sulfide control, each having its appropriate field of usefulness. Of the possible methods of control in force mains, air injection is pre-eminent because of its simplicity, economy, and generally effective results.

Installations

In 1942, Ewald Lemcke, then Chief Engineer of the Orange County, Calif., Joint Outfall Sewer, suggested putting compressed air into one of the force mains of the County. This was done and complete sulfide control was obtained. The method has now proved itself in many installations. Those for which information is available are discussed below.

Buena Park Force Main, Orange County, Calif.

This is the first force main (east iron, 8-in. diam, 2.14 miles long) in which compressed air was used. In Figure 1 are shown the results of tests conducted in 1947 with no sulfide-con-

trol treatment, with chlorine treatment, and with 35 cfm of air.

With no treatment, total sulfide concentrations at the end of the force main averaged 5 mg/l at the beginning of February and nearly 10 mg/l at the end of March. A single day without treatment, following chlorination, showed 3 mg/l of sulfide, which seems to indicate that generation was depressed by a carry-over effect of chlorination.

These data show that sulfide was controlled by both chlorine and compressed air during the time of the tests. In the summer, a chlorine dosage of 120 lb/day was insufficient, but then compressed air did not give complete control either. Therefore, in the summer, a small amount of chlorine was used in conjunction with the air.

Compressed air was used in this line until the sewage was diverted to a gravity sewer in 1953.

Orangethorpe Force Main from Magnolia Pump Station, Orange County, Calif.

In Figure 2 are the results of tests with compressed air. The tests on this line (reinf. concrete, 16-in. diam, 2.0 miles long) were conducted in 1947. Sulfide concentrations at the end of the force main were averaging about 8 mg/l. Use of 80 cfm of air eliminated all but a small amount of insoluble sulfide. Compressed air was used until the sewage was diverted to a gravity sewer in 1953.

Los Angeles County Sanitation Districts' Joint Outfall C (Long Beach), Calif.

In Figure 3 the irregular profile of this line (reinf. concrete, 54-in. diam, 2.4 miles long, 40 mgd) can be seen. Because of this profile, air blocks are a problem. A downward slope does not produce an air block where the slope does not exceed the hydraulic gradient of the line. There are, however, three places where air blocks presumably do arise when compressed air is used in this line. When air is injected at a rate of 60 cfm, the pressure at the pump header is 23 to 26 psi; it is 3 to 4 psi lower when air is not used.

Air is applied at a rate of 60 cfm during the day when the sewage is strong, and at a 30-cfm rate at night when the strength is lower. Sulfide concentrations at the pumps range from 0 to 1.0 mg/l. Sulfide generation in the force main without air averaged 0.66 mg/l; the buildup

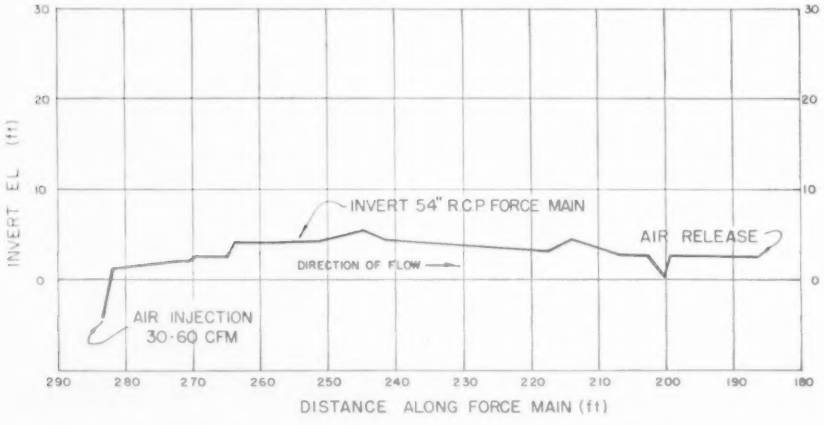

FIGURE 3.—Profile of Joint Outfall C, Long Beach, Calif.

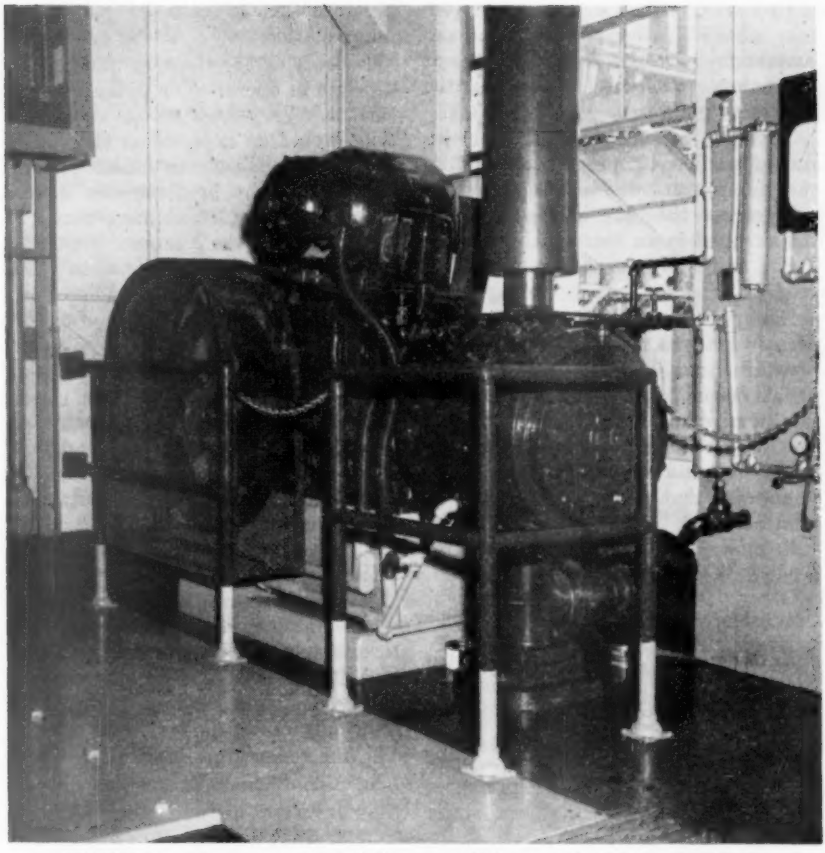

FIGURE 4.—Compressor installation for sulfide control of Joint Outfall C, Long Beach, Calif.

when air is used is 0.19 mg/l. This reduction of 0.47 mg/l (total sulfide) seems small, but it is enough to keep dissolved sulfide at the end of the line within safe limits. Taking into account the large flow, a large amount of any treating chemical (e.g., 1,800 lb/day of chlorine) would be required for equal results.

Air injection has been in operation in this line since 1948. Figure 4 is a photograph of the compressor installation.

Bismarck, N. Dak.

Without the addition of compressed air, this force main (20-in. diam, 0.66 miles long, 0.23 mgd, intermittent flow) produced 9 mg/l of sulfide even in February with an air temperature of 20°F and a sewage temperature of 50°F. Use of 50 cfm of compressed air seems to accomplish control. Tests have not been made to ascertain whether less air will suffice.

South Laguna Sanitary District, Calif.

The sampling point on the line (reinf. concrete, 12-in. diam, 1.03 miles long, 0.2 mgd, intermittent flow) was at the end of the pipe following the air release. Any sulfide produced in that section was included.

In January, with a sewage temperature of 66°F, the total sulfide concentration increased from 0.5 mg/l at the pump station to 11.6 mg/l at the treatment plant.

A 5-cfm compressor had been installed so that it operated only while the pump ran, which was about 20 per cent of the time in the daytime; this resulted in an average air input of 1 cfm and sulfide concentrations were reduced to about 7 mg/l.

Tests were made with a large compressor in June when the sewage temperature was 73°F. At that time, sulfide concentrations at the pump station averaged 1.2 mg/l; at the end of the line, with varying air input, the concentration averaged 0.6 mg/l. Thus it appears that 6 cfm, or perhaps 10 cfm at peak summer temperatures, will suffice for the degree of control needed.

Oceanside, Calif.

Here air injection is practiced on a combined force main and inverted siphon. The line is a 24-in., concrete-lined steel pipe, 5.5 miles long. The average flow is 1.9 mgd. At the present rate of flow, pumping pressures are not much greater than the static pressure, being about 44 psi at the pump station.

In July 1958, the city placed this pipeline in operation to pump primary effluent. Very high sulfide concentrations would be expected at the end of the line if no counter-measures were employed. The problem was complicated by the fact that there were two high places in the line and it was decided to add air at three points. Figure 5 shows a condensed profile of this line.

The first point of injection is at the pump station at the primary treatment plant. The input here is 15 cfm of free air which is subsequently relieved at the first high point. An atmospheric break was not practical because of the pressure and automatic air release valves are notoriously troublesome on pipes carrying sewage, therefore, a tap was made at the top of the pipe to connect a throttling pipe ¼ in. in diam and 4 ft long. The throttling pipe can be readily replaced if a larger size becomes necessary to avoid stoppages; however, there has been only one stoppage in 12 months. The throttling pipe is connected to a 1-in. pipe 1,500 ft long which conveys the mixture of air and water to a con-

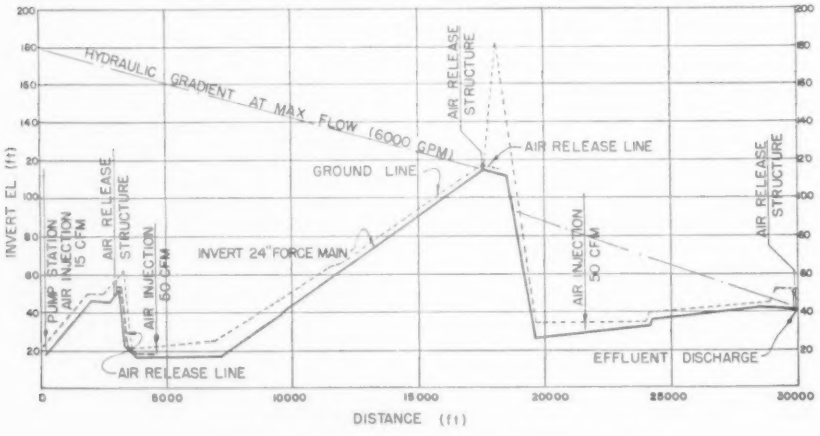

FIGURE 5.—Profile of force main at Oceanside, Calif.

venient pump station on the sewage collecting system. There it discharges into the wet well. A second air compressor takes suction out of this wet well and injects 50 cfm of air into the force main. In this way the air released upstream does not escape to the atmosphere.

At the second high point there is an atmospheric break, provided by a 4-ft square chamber. The air removed here goes into a soil diffusion bed of crushed rock which is 3 ft wide, 75 ft long, and is buried 10 ft or more. Odor control is absolute (4).

At the third injection point the air input rate is 50 cfm. This force main terminates at a valve chamber at the dam of Whelan Lake, where the used water is discharged. The air seems to leave the water without foam formation, but the turbulence caused by belching at the chamber whips up foam. This is not of great consequence in the isolated environment, although plans have been made to install an air release at a high point 1,500 ft from the end of the line to avoid all unsightliness.

When the air compressors are shut off, total sulfide concentrations of 7 to 18 mg/l have been observed at the end of the pipeline; when the compressors are on, sulfide concentrations are either present in trace amounts or altogether absent.

It is reasonable to suppose that a measurable BOD reduction would occur when compressed air is used in a line like this. The predicted average sulfide output in this line at December's temperatures is 10 mg/l and production of this much sulfide from sulfate makes 20 mg/l of oxygen available for oxidation of organic matter. It seems that at least this much reduction of BOD should be found when air is used in a line.

During December 1958, BOD samples were taken at the pump station and at the end of the line, after making an allowance for the time of passage. The average BOD values were, respectively, 146 and 84 mg/l. This is a reduction of 64 mg/l or 44 per cent. From these results it appears that elemental oxygen is used about three times as fast as oxygen from sulfate. This is not surprising, since there are innumerable species of microbes which will use elemental oxygen, yet only a few will use sulfate.

The amount of oxygen used, as judged by the BOD reduction, is about 1,000 lb/day and the amount supplied from the compressor is about 2,500 lb/day. This indicates that a much greater percentage of the injected oxygen is absorbed by sewage in a force main than in aeration tanks.

Discussion

In most cases air injection can be expected to be completely effective in preventing sulfide buildup, and in any case it will greatly reduce generation. While it cannot be used in some existing mains because of their profile, it usually can be incorporated into the design of new mains.

The fact that the applied air, traveling along the top of the pipe as a thin layer or as bubbles, can be so effective is a bit surprising when one considers the slow uptake of oxygen in partially filled gravity sewers. The effectiveness can probably be accounted for by the turbulence which is associated with passage of the air through the pipe. If there is an upward slope in the direction of flow, bubbles of air pass up the pipe, speeding ahead of the water. Even when the pipe is level, it is unlikely that a continuous layer of air will form along the top of the pipe. Flow would be in the unstable region of an almost-full pipe, and would tend to be alternately, full and less-than-full. It seems probable that the air is carried along as large bubbles even in a level pipe. Only where there is an air trap will the sewage flow in a way which is normal for partially filled

sewers. In one small, cast-iron main (now abandoned) the initial injection of air caused dislodgment of black sludge in great quantities.

Turbulence, which it is presumed results from air in the main, could easily account for a rate of solution of oxygen much greater than that which obtains under ordinary flow conditions in a gravity sewer. Besides, rate of solution is proportional to the absolute pressure. Thus if the pressure in a pipe is equal to a 32-ft column of water, the rate of solution, other things being equal, will be twice as great as at atmospheric pressure.

Design of Air-Injection Systems

When air injection is planned, the first question is—"How much air should be used?"

A review of the preceding six cases, along with other fragmentary information, does not provide any clear guide in this respect. It is hoped that results from other installations will, by enlarging the range of information, help to clarify the picture in respect to the determinative factors.*

The one fact that is clear is that the amount of sewage carried by a filled pipe is not an important factor in determining the air requirement. The biological film on the pipe wall goes right on producing sulfide as long as nutrients are present whether the sewage is flowing rapidly or slowly, or is standing. Compressors should not be connected to go off and on with the pumps; they should run continuously.

The amount of oxygen required is roughly proportional to the area of biological film or of pipe wall. Thus the oxygen requirement per foot of pipe length is proportional to the diameter of the pipe. Air which has been injected has its oxygen absorbed only slowly and there is no serious reduction in the rate of oxygen absorption until there is substantial depletion of the oxygen. Therefore, the length of pipe does not make much difference until this length is great enough to cause substantial depletion of oxygen. That length is usually not less than a mile.

It would not be difficult to develop a formula for estimating the oxygen requirements for sulfide control in a filled pipe, but estimating the amount of air to inject is another matter since there is so little information about rates of solution of oxygen from the injected air. Pressure certainly makes a difference, with higher pressures favoring more rapid solution. However, there is a lack of information about the effect of slope of the pipe on rate of oxygen absorption, and about the relationship between the amount injected and the amount dissolved.

The designer is best advised to consider, as a basic estimate, a rate of 1 cfm of air per inch of pipe diameter. If the average pressure in the pipe line exceeds 50 ft of water, air input may be reduced inversely to the absolute pressure. If the peak effective BOD exceeds 400 mg/l, air input should be increased, possibly in proportion to the effective BOD. If the line is more than a mile in length, air input should be increased proportionally. However, no increase for length is necessary if the oxygen input in lb/day exceeds the daily transmission of 5-day BOD.† This assures against excessive oxygen depletion in the air. These, of course, are tentative suggestions.

After estimating the probable air requirement, a compressor should be sized to deliver twice that amount, with provision to reduce the speed to a level that will accomplish control without power wastage.

It is undesirable to use an air storage reservoir with pressure-controlled

* The author will be grateful for additional information in this regard.

† It can be assumed that one pound of oxygen is contained in about 60 cu ft of air, assuming an elevation of 0 to 2,000 ft above sea level.

cutout, as this wastes power and is harder on the machinery.

Some agencies have had trouble with compressors that they have installed for sulfide control. The reason has been that the compressors were light, high-speed units, not suitable for continuous operation.

The method of introduction of the air is unimportant. Attempts to diffuse the air could not have more than a very local effect and probably will not merit the expense of extra facilities.

A pressure main commonly rises greatly in elevation in or near the pump station. By adding air at the highest convenient point near the station, power requirements may be reduced.

Summary

A collection of data relative to sulfide generation in force mains and other filled sewers provides the basis of an equation (Equation 9) which will aid the engineer in anticipating possible sulfide conditions. By means of this equation the maximum sulfide buildup can be estimated. The actual buildup is often less than this amount for a variety of reasons. Two lines showed much higher generation than predicted by the equation. These are cast iron lines carrying sewage containing a substantial quantity of sea water. It is postulated that anaerobic bacterial corrosion of the iron may occur in these cases which may be related to the abnormally high sulfide production.

Injection of compressed air into a force main or other filled pipe is a useful method of sulfide control, usually accomplishing a large reduction or complete elimination of sulfide generation. Data on six installations are presented.

It appears that the air requirement is usually about 1 cfm of air per inch of pipe diameter, with adjustments for abnormal lengths, pressures, or sewage strengths. Final determination of the minimum requirement may have to be by trial after installation.

It is hypothesized that the relatively high efficiency of dissolving of oxygen from the injected air is due in large part to the turbulence caused by large bubbles traveling in the pipe.

Acknowledgment

So many individuals have assisted in this investigation that proper credit and thanks cannot be expressed individually. This is regrettable, for one need only glance at Table I to understand the magnificent cooperation that has been extended to the author. To the Australian workers, Mr. D. K. B. Thistlethwayte, Mr. E. F. Borrie, and Mr. W. J. Davy, and their co-workers, who furnished a substantial block of data and made helpful suggestions regarding the article, the author is very much indebted.

This research project was carried forward under the sponsorship of the Portland Cement Association.

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DEEDS AND DATA

"A modest man is usually admired—if people ever hear of him."—E. W. Howe

Highlights from the Annual Reports of Arlington, Va., Cincinnati, Ohio, East Hartford, Conn., Gary, Ind., Latrobe Valley Water and Sewerage Board, Traralgon, Australia, Middlesex County Sewerage Authority, Sayreville, N. J., Minneapolis-St. Paul, Minn., Racine, Wis., South Bend, Ind., and Winnipeg, Man.

MICHAEL H. GULA, *Superintendent, Arlington, Va.;* ARTHUR D. CASTER, *Principal Sewage Disposal Engineer, Cincinnati, Ohio;* EDWARD A. KOWSZ, *Plant Operations Engineer, Metropolitan District, Hartford, Conn.;* W. W. MATHEWS, *Superintendent, Gary, Ind.;* JOHN B. MULVANEY, *Chairman Latrobe Valley Water and Sewerage Board, Traralgon, Australia;* SOL SEID, *Chief Engineer, Middlesex County Sewerage Authority, Sayreville, N. J.;* KERWIN L. MICK, *Chief Engineer and Superintendent, Minneapolis-St. Paul, Minn. Sanitary District;* THOMAS T. HAY, *Superintendent, Racine, Wis.;* LOUIS P. BOURDON, *Superintendent, South Bend, Ind.;* AND N. S. BUBBIS, *General Manager and Chief Engineer, Greater Winnipeg Sanitary District, Winnipeg, Man.*

Chemical Treatment

Even though chemical treatment of wastes at Cincinnati's Little Miami Works was not necessary, the flocculators have been in operation since Aug. 1958. This method of operation is based on the results of earlier studies which indicated natural flocculation would be enhanced by gentle stirring. Suspended solids removals have increased by approximately 7 per cent.

The chemical treatment plant of the Middlesex County (Sayreville, N. J.) Sewerage Authority went into operation on Jan. 14, 1958. This plant now has a capacity of 52 mgd and an ultimate design capacity of 78 mgd. Combination flocculation-clarification tanks are used and the coagulation chemicals are chlorinated copperas and lime.

Industrial Wastes

Since 1954, surcharge revenues from industrial sources in Cincinnati, Ohio, have been declining. The number of accounts has stayed about the same but revenue went down from $715,238 in 1954 to $413,746 in 1958. This decrease is attributed to changes in manufacturing methods, better housekeeping, installation of treatment or pretreatment facilities, wastewater reuse, urban renewal, and expressway construction. While this reduction in waste discharges appears commendable, it does have a serious side, for many of these same industrial groups petitioned the Cincinnati Council to incorporate extra facilities into the plant design—facilities which require a yearly income of approximately $500,000.

Damaged gas piping in a digester at the Racine, Wis., treatment plant has been attributed to excessive quantities of hair contained in a tannery waste. The cost of cleaning and repair was $1,767 and the quality of digestion was seriously affected.

Early in 1957 the city of St. Paul asked the Minneapolis-St. Paul Sanitary District to help locate the source

of a highly acid waste which was causing serious corrosion of pump parts at a St. Paul pumping station. Treatment-plant laboratory personnel found the waste to be a ferric chloride solution produced by a steel- and copper-etching process. The result was that the industry stopped discharging the acid waste to the sewer only to haul it directly to the treatment works where it is used in conditioning sludge. The Sanitary District purchases the ferric chloride for only the handling and transportation costs.

The following industries are direct participants in the Middlesex County (N. J.) Sewerage Authority: Union Carbide Plastics Co., Benzol Products Co., Heyden Chemical Co., Anheuser-Busch, Inc., Peter J. Schweitzer, Inc., Hercules Powder Co., and National Lead Co. In addition, many other industries are indirect participants by virtue of their connection to a sewerage system of a participating municipality. This large and varied industrial contribution results in a waste which has an unusually large proportion of its BOD in the soluble fraction. As a consequence, high BOD removals are not obtained nor were any anticipated.

Land Disposal

The outfall project of the Latrobe Valley (Australia) Water and Sewerage Board was brought into full operation in Aug. 1957 when the remaining five miles of open channel and the 1,080-mil gal holding ponds were completed.

The open channel section of the outfall has operated satisfactorily and regular testing has established that seepage from the channel is negligible. However, some short lengths have been lined as a precautionary measure.

The waste discharged to the outfall totals approximately 6.9 mgd;* of this, 5.8 mgd is paper wastes, 0.8 mgd is gas wastes, and 0.3 mgd is domestic sewage.

In Dec. 1957 a series of test plots were prepared at the land disposal area. The plots were sown with a variety of grasses and irrigated by spray and flood methods as well as by seepage. Comparisons with untreated control plots showed substantial improvement in growth for the treated areas.

Additional tests on land of better quality also showed similar improvement. As a matter of record, results from the various test plots are encouraging to the point that the Board has indefinitely deferred action on proposals for ocean disposal. Future sewage works will consist mainly of development of the land disposal project.

Maintenance

One of the two primary digesters at the Arlington, Va., plant suffered serious damage when a scum cap 8 to 12 ft deep shifted its weight. After dewatering and attempts to use pumps and air lifts, a 24-ft bucket-type elevator was used to remove the remaining material. A 16-ft extension was added to the machine and the lengthened unit was placed in the dome of the digester at an angle of approximately 85 deg. A sheet metal, truss-supported discharge chute, constructed in sections and bolted together, extended over the side of the digester and sludge was discharged to an ash truck borrowed from the county's incinerator.

The material in the bottom of the digester was of a stringy, matted nature except for one to two feet of sand. The total quantity of material removed was close to 500 cu yd and its solids content was between 18 and 23 per cent. The bucket operation took approximately 200 hr for completion including repair time.

The extent of the damage was as follows:

* U. S. gallons.

1. The gas line was broken next to the flange located about 15 ft in from the sidewall.
2. The combination sludge-recirculation and sludge-inlet line was pushed out from the wall and the originally upturned elbow was turned down.
3. The supernatant selector screen was on the tank bottom.
4. The concrete pipe-support pedestal had three breaks in it and the vertical pipe grouting was broken.
5. The south pipe-support strut was cracked.
6. The long-line strut was broken at its pedestal attachment and cracked near the column near the discharge point.

After the No. 1 digester was in active service, digester No. 2 was cleaned. Its condition is described below:

1. The main concrete pedestal was found to be cracked.
2. All the grouting for the base supports for the vertical piping was broken.
3. The supernatant selector line was loose and tilted.
4. The gas line was tilted.
5. The discharge from the combination sludge-recirculation and sludge-inlet line was turned over and its discharge was directed to the tank bottom.
6. The suction line for the recirculating pumps was out of position by about 45 deg.

Nearly 750 cu yd of bottom sludge was removed from this digester by the bucket machine.

Metering and Sampling

The following is a brief description of the sampling methods used at Minneapolis-St. Paul treatment works:

Screenings and grit are sampled daily, with 24-hr composite samples made up from hourly grabs taken from the conveyor belts. The grab samples are placed in pails with perforated bottoms to permit drainage of any excess water, after which the weight per cu ft is determined. The daily quantities in cu ft are computed from the number and estimated size of truckloads hauled to the dump. The moisture and volatile matter are determined in the laboratory.

Samples of sewage from the various plant units are collected by automatic samplers which proportion the sample to the rate of sewage flow. Once a shift the 1-gal aluminum sample cans are removed from the automatic samplers and placed in a refrigerator. The pipe lines to the automatic samplers are backwashed once a shift with plant effluent. Twice a week the sampler parts are brushed and washed with a copper sulfate solution and the raw sewage sampler lines are blown with compressed air.

The raw sludge samples are 24-hr composites of grabs from sampling cocks on the sludge pumps. From each pump one sample is taken 15 min after starting, then one every 20 min during the pumping, and one when the pump is to be stopped. Sludge is allowed to flush through the sampling pipe before the sample is collected. Approximately one quart of sludge is withdrawn each time, and after stirring, a 50-ml ladleful is placed in the sample can.

The supernatant liquor pumped from the sludge concentration tanks is sampled by collecting two 100-ml ladlefuls every 15 min during pumping.

The concentrated sludge samples are 24-hr composites of the sludge going to the conditioning tanks and they are obtained by taking two 100-ml ladlefuls per hour from a bucket of each bucket-elevator. One to two gallons of composite sample are thus obtained.

The filter cake samples are 24-hr composites collected by applying a cookie cutter to the discharge side of the vacuum filter. One "cookie" is collected per hour from each filter. The sludge and filter cake samples are

TABLE I.—Operating Results from Two Activated Sludge Plants

Treatment Plant	Operating Yr. Ending	Est. Pop. Served	Sewage Volume				Sewage Temp. (°F)			Sewage Strength (mg/l)				Efficiency of Treatment (%)						Grit Removed (cu ft/mil gal)
			Avg (mgd)	Max Day (mgd)	Min Day (mgd)	Per Cap (gpd)	Avg	Max	Min	Influent		Effluent		Primary Unit		Secondary Unit		Over-all		
										BOD	SS	BOD	SS	BOD	SS	BOD	SS	BOD	SS	
1. Gary, Ind.	12/58	155,000	23.8	—	—	154	60	—	—	343	468	19	13	70	73	81	89	95	97	5.2
2. South Bend, Ind.	12/57	140,000	29.9	—	—	214	—	—	—	109	178	12	17	37	73	83	65	81	87	1.4
3. South Bend, Ind.	12/58	140,000	31.7	—	—	226	—	—	—	115	159	10	15	25	65	88	73	88	88	1.4

Treatment Plant	Primary Sedimentation				Activated Sludge							Disinfection	
	Surface Overflow Rate (gpd/sq ft)	Raw Sludge			BOD Loading (lb day/1,000 cu ft)	Air Use (cu ft/lb of BOD removed)	Air Use (cu ft/gal of sewage)	Aeration Period (hr)	Return Sludge (%)	Mixed Liquor		Sludge Index	Cl_2 Dosage (mg/l)	Effluent Quality (MPN/ml)
		Volume (cu ft/mil gal of sewage)	Dry Solids (lb/mil gal of sewage)	Solids Conc. (%)						DO (mg/l)	SS (mg/l)			
1. Gary, Ind.	—	662	3,783	5.3	19	769	0.52	5.6	43	2.4	3,038	0.97	0	4,126
2. South Bend, Ind.	—	573	1,420	4.0	20	1,433	0.66	3.8	35	3.0	1,336	1.41	—	—
3. South Bend, Ind.	—	616	1,900	4.8	30	970	0.62	3.3	30	3.6	1,676	1.21	—	—

Treatment Plant	Sludge Digestion												Sludge Filtration				Operating Cost ($/mil gal)
	VS Loading (lb/day/1,000 cu ft)	VS Red. (%)	Temp. (°F)	Vol. Acids (mg/l)	Alk. (mg/l)	pH	Supernatant		Gas								
							Volume (cu ft/mil gal of sewage)	Solids Conc. (mg/l)	Produced (cu ft/day/cap)	Produced (cu ft/lb VS fed)	Used (%)	Heat Value (Btu/cu ft)	CO_2 (%)	Dry Yield (psf/hr)	$FeCl_3$ Fed (%)	CaO Fed (%)	TS in Cake (%)	
1. Gary, Ind.	70	—	79–91	—	—	6.9	—	—	1.1	3.9	—	604	30	—*	—	—	—	27.20
2. South Bend, Ind.	124	—	91	—	—	—	509	—	1.4	8.7	—	—	—	—†	—	—	—	17.46
3. South Bend, Ind.	162	—	88	—	—	—	470	—	1.4	6.6	—	—	—	—‡	—	—	—	18.55

* Drying beds used.
† About 69% of wet sludge trucked away; 31% to drying beds.
‡ About 80% of wet sludge trucked away; 20% to drying beds.

deposited in milk cans having tight-fitting covers to minimize loss of moisture by evaporation.

The sludge filtrate samples are 24-hr composites of 200-ml hourly grabs collected from the filtrate receivers.

Toward the end of each shift, samples collected during each 8-hr period of operation are taken to the laboratory and placed in the refrigerator to await compositing on the following morning.

Thirteen municipalities and seven industries are direct participants in the Middlesex County (N. J.) Sewerage Authority and charges are assessed on the bases of: flow, BOD, SS, and chlorine demand. With this type of arrangement, provisions for metering and sampling must be incorporated into the over-all operating plan.

Flow measurement is accomplished at individual meter chambers at each point of discharge and Parshall flumes, Kennison nozzles, and Venturi tubes are utilized. Composite samples are automatically collected using a proportional sample developed jointly by the Authority and the Hydra-Numatic Sales Co.

After installation of the samplers, rags soon clogged the open end of the suction lines. Suction strainers were better than open ends but they clogged too. Finally, several types of deflectors were tried in conjunction with the strainers. One type of deflector has been especially successful and it is now undergoing extensive testing.

Operation

Operating data from nine treatment plants appear in Tables I and II. Data in Table I are from activated sludge plants and data in Table II are from primary and chemical treatment plants.

Sludge Handling

Beginning in Nov. 1954, all of the sludge at the Minneapolis—St. Paul plant has been filtered through 32- by 32-mesh Saran cloth screen. This 32-mesh cloth affords a relatively porous filter media compared with the closely woven 8-oz Canton flannel filter cloth previously used. Use of the 32-mesh cloth eliminates most of the "blinding" difficulties which had been increasingly troublesome with the cotton cloths the past few years. Marked economies and improvement in operating conditions have been experienced. The filtrate which is returned to the settling tanks is considerably higher in suspended solids content when the 32-mesh cloth is used, but little impairment of the final plant effluent has been evident. The average service life of the six Saran cloths replaced during 1957 was 9,329 hr, compared with only 433 hr for flannel cloths in 1954. The maximum service life for a Saran cloth was 23,257 hr at the close of 1957.

Beginning in Apr. 1957 a limited supply of waste ferric chloride solution has been obtained from a local company which uses it in a metal etching process. The company delivers it by truck in 13-gal rubber drums and dumps it into the underground ferric chloride storage tank. The cost is less than half that of commercially produced ferric chloride solutions purchased in tank car lots. The waste ferric chloride solution received in 1957, however, constituted only 6.3 per cent of the total iron usage that year.

The use of waste carbide lime slurry instead of pebble quicklime as one of the sludge coagulant chemicals was continued. The slurry, as delivered in a tank truck, contains 25- to 30-per cent solids averaging 71-per cent CaO. Storage for 25,000 gallons is provided. The slurry is fed through a diaphragm slurry pump, adjustable for different rates of feed. In 1957, 198 truck loads were received containing 765 tons of CaO at an average delivered price of $12.24/ton of CaO, compared with $20.55 for pebble quicklime per ton of available CaO, a saving of approxi-

TABLE II.—Operating Results from Six Primary Plants and One Chemical Treatment Plant

Treatment Plant	Operating Yr. Ending	Est. Pop. Served	Sewage Volume				Sewage Temp. (°F)			Sewage Strength (mg/l)				Eff. of Treat. (%)	
			Avg (mgd)	Max Day (mgd)	Min Day (mgd)	Per Cap (gpd)	Avg	Max	Min	Influent		Effluent			
										BOD	SS	BOD	SS	BOD	SS
1. Arlington, Va.	6/57	174,000	14.1	—	—	81	—	—	—	278	313	152	69	45	78
2. Arlington, Va.	6/58	174,000	16.2	—	—	93	—	—	—	278	297	148	79	47	72
3. Cincinnati, Ohio[a]	12/58	120,000	9.7[b]	—	—	—[b]	—	—	—	173	241	104	70	40	71
4. E. Hartford, Conn.	12/56	16,600	2.9	4.8	1.1	177	65	—	—	195	257	136	135	30	45
5. E. Hartford, Conn.	12/57	17,080	2.7	4.8	0.7	160	68	—	—	245	255	163	142	33	44
6. Minneapolis–St. Paul, Minn.	12/57	1,023,000	149.0	—	—	145	62	—	—	229	291	141	94	39	68
7. Racine, Wis.	12/58	86,000	14.8	26.8	5.9	173	58	71	44	182	220	123	57	32	74
8. Winnipeg, Man.	12/58	420,600	33.4	—	—	79	60	—	—	316	310	167	114	46	60
9. Middlesex Co., N. J.[c]	12/58	—	35.2	—	—	—	—	—	—	447	285	382	82	14	71

Treatment Plant	Grit Removed (cu ft/mil gal)	Primary Sedimentation				Disinfection	
		Surface Overflow Rate (gpd/sq ft)	Raw Sludge				
			Volume (cu ft/mil gal of sewage)	Dry Solids (lb/mil gal of sewage)	Solids Conc. (%)	Cl_2 Dosage (mg/l)	Effluent Quality (MPN/ml)
1. Arlington, Va.	2.5	—	586	1,720	4.7	—	—
2. Arlington, Va.	1.9	—	514	1,510	4.7	—	—
3. Cincinnati, Ohio[a]	0.9	—	445	1,790	6.4	—	—
4. E. Hartford, Conn.	1.7	363	621	2,333	5.8	—	—
5. E. Hartford, Conn.	2.4	338	533	1,710	4.9	—	—
6. Minneapolis–St. Paul, Minn.	6.9	—	497	2,120	6.8	—	—
7. Racine, Wis.	—	—	272	1,410	7.9	—	—
8. Winnipeg, Man.	1.3	—	279	1,560	4.5	—	—
9. Middlesex Co., N. J.[c]	—	—	7,350	3,120	0.7	15.9	—[d]

TABLE II.—*Continued*

Treatment Plant	Sludge Digestion													Sludge Filtration				Operating Cost ($/mil gal)
							Supernatant		Gas									
	VS Loading (lb/day/1,000 cu ft)	VS Red. (%)	Temp. (°F)	Vol. Acids (mg/l)	Alk. (mg/l)	pH	Volume (cu ft/mil gal of sewage)	Solids Conc. (mg/l)	Produced (cu ft/day/cap)	Produced (cu ft/lb VS fed)	Used (%)	Heat Value (Btu/cu ft)	CO_2 (%)	Dry Yield (psf/hr)	$FeCl_3$ Fed (%)	CaO Fed (%)	TS in Cake (%)	
1. Arlington, Va.	—	—	—	—	3,115	—	364	16,000	—	—	—	—	—	—	—	—	29	44.42
2. Arlington, Va.	—	79	—	—	2,765	—	351	10,000	1.1	—	—	—	—	—	—	—	28	40.89
3. Cincinnati, Ohio[a]	—	—	—	—	—	—	—	—	0.9	—	45	—	36	1.5	6.1	—	31	—
4. E. Hartford, Conn.	122[c]	47	95[c]	—	1,507	6.7	—	—	1.6	5.4	100	683	31	5.3	2.0[d]	0	35	59.37
5. E. Hartford, Conn.	88[c]	60	96[c]	—	1,683	6.7	—	—	1.5	7.5	94	—	—	5.9	2.6[d]	0	30	66.57
6. Minneapolis-St. Paul, Minn.	—	—	—	—	—	—	—	—	—	—	—	—	—	3.1[e]	1.1[f]	2.9[f]	28	15.15
7. Racine, Wis.	79[c]	—	94	—	—	7.2	—	—	0.7	5.6	70	—	—	—[g]	—	—	—	22.80
8. Winnipeg, Man.	—	—	—	—	—	—	—	—	0.8	10.0	30	—	34	5.3[h]	1.7	8.4	29	15.87
9. Middlesex Co., N. J.[i]	—	—	—	—	—	—	—	—	—	—	—	—	—	—[k]	—	—	—	—

[a] Little Miami Sewage Works.
[b] Flow substantially reduced because of sewer construction.
[c] Two-stage digestion; value is for primary tank.
[d] Elutriated sludge.
[e] Raw sludge.
[f] Based only on sludges actually conditioned. If based on total weight of sludge filtered, averages reduce to 2.1% CaO and 0.6% $FeCl_3$.
[g] Drying beds used.
[h] Only 25% of sludge filtered; remainder to lagoons.
[i] Chemical treatment plant.
[j] 91% of sample contains less than 0.2 coliform org./ml.
[k] Sludge thickened, stored, and barged to sea.

mately 40 per cent. The carbide lime slurry appears to be as effective as quicklime and is easier to handle and feed.

The Greater Winnipeg (Man.) Sanitary District maintains 12 sludge lagoons having a total area of 15.6 acres. All digested sludge in excess of the capacity of one 10- × 10-ft vacuum filter is sent to the lagoon area for drying. Two of the larger lagoons, totaling 6.8 acres in area, were cleaned in three days by using two 10-yd scrapers. Nearly 2.6 mil lb of dry solids were removed in this cleaning operation.

At South Bend, Ind., a portion of the liquid sludge is hauled away in two 1,500-gal sludge trucks. To facilitate loading, a swivel-joint tank-truck loader is located at the rear of the digester. The liquid sludge is deposited on farms, parks, and playgrounds. During 1958, nearly 80 per cent of the sludge withdrawn from the digesters was disposed of in this manner.

The chemically precipitated sludge from the Middlesex County (N. J.) treatment works is first pumped to a thickening tank where the solids content is increased from 0.5 to about 6.5 per cent. Two tanks are used alternately and each tank provides a detention of about 4 hr for the supernatant and 12 hr for the sludge. Thickened sludge is then pumped to sludge storage tanks which are also used to store grit.

Each tank contains recirculation equipment and a nozzle for washdown purposes. From the storage tank, sludge and grit are pumped to a sludge barge with a capacity of 3,300 tons—the equivalent of one storage tank. Sea disposal is at a point designated by the Corps of Engineers.

WASTEWATER TRANSFORMATION AT AMARILLO*

I. MUNICIPAL PHASE

By Clarence H. Scherer

Superintendent, Water Reclamation and Sewerage Treatment Plant, Amarillo, Tex.

The water reclamation and sewage treatment plant of the city of Amarillo, Tex., has been providing a dependable and satisfactory source of cooling and boiler-makeup water for the Texas Company's Amarillo Refinery since Mar. 1955. Many factors—the city's need for additional sewage treatment facilities, the depletion of underground water supplies, and revenue requirements of an expanded treatment works, together with the successes in Baltimore, Md., Big Spring, Tex., and Enid, Okla.—prompted officials of Amarillo and the Texas Company to give serious consideration to the use of treated sewage in the Company's new gasoline products refinery.

In 1954, a contract was signed by both parties which stipulated that (a) the city of Amarillo would construct a completely new 4.5-mgd sewage treatment plant consisting of activated sludge treatment and at least three days' storage of treated sewage, a pumping station and transmission line from the treatment plant to the refinery, and other units as may be necessary to provide suitable industrial water, (b) the Texas Company would provide such additional water treatment as may be necessary to render the reclaimed effluent suitable for their

* Presented at the 31st Annual Meeting, Federation of Sewage and Industrial Wastes Assns.; Detroit, Mich.; Oct. 6–9, 1958.

purposes, and (c) the city of Amarillo would provide an effluent with the following basic qualities:

1. pH between 6.8 and 9.0,
2. Suspended solids not to exceed 25 mg/l,
3. Biochemical oxygen demand not to exceed 25 mg/l,
4. Total dissolved solids not to exceed 1,000 mg/l, and
5. Chlorine residual of delivered water at least 0.1 mg/l.

It was understood by both parties that these limits were essentially arbitrary, i.e., they could be raised or lowered within reason at the request of the industry. It is evident too that the effluent standards should be easily met by an activated sludge plant, although they are possibly more stringent than necessary for some industrial uses of reclaimed sewage.

Treatment Plant Description

The new activated sludge plant is located about 10 miles north of Amarillo on the grounds of the old primary treatment plant. It was completed and placed in operation during Mar. 1955. Although the sewage flow at that time was in excess of 7.5 mgd, the new treatment works was designed and built with a capacity of only 4.5 mgd—the amount of water involved in the reclaimed-water contract. The remainder of the sewage flow, about 3 mgd, continues to flow through the old primary treatment plant. The new plant was built in a way which will make expansion relatively simple and economical. This expansion will take place as soon as the demand for reclaimed sewage exceeds the capacity of the present facilities or if the use of the receiving stream approaches the point where primary treatment for part of the sewage will no longer be adequate.

The sewage treatment plant is of the conventional activated sludge type.

The average settling time in the primary tanks is 1.2 hr and the average aeration time is 7 hr. The air application is 600 cu ft per pound of BOD added. Two-stage, heated digesters provide a capacity of 3 cu ft/capita. With close controls, this capacity has proved adequate. Final sedimentation detention is 2.3 hr and the surface overflow rate is 590 gpd/sq ft.

The effluent is storaged in a 9-mil gal earthen reservoir, having a maximum depth of 16 ft. This reservoir provides at least a 3-day "buffer" against normal and unusual plant upsets which may temporarily prevent the production of industrial water. The effluent reservoir has been seeded successfully with several varieties of game fish.

Reclaimed water is pumped 10 miles and lifted 330 ft to either the company's reservoir or directly to their water treating units. All pumped water is chlorinated at the pump intakes at the sewage treatment plant.

Plant Operation

There has been little difficulty in meeting the minimum water quality requirements as set forth in the contract. However, it has been found that the production of industrial water of a constant quality and quantity using the activated sludge process requires a much closer watch on the performance of all units than would normally be required in a plant whose only purpose is to prevent pollution.

Sampling schedules are set up for the primary purpose of anticipating and avoiding plant upsets. In addition to the normal control tests, the Amarillo personnel collect hourly grab samples of raw sewage and run qualitative, toxic-metals tests on them. They also run phosphates, dissolved solids, hardness, and other tests on daily composite samples. A measure of the success of this "preventive" control program is illustrated by the fact that during the first three years of operation there have been only two

short periods when the Company was forced to discontinue use of the effluent because of severe sewage treatment plant upsets. On both of these occasions it was found that the plant upsets were caused by large quantities of a toxic industrial waste.

Although it was assumed that the liquid industrial wastes in the raw product being received at the sewage treatment plant were affecting the cost of production of reclaimed water, the extent was not fully realized until Jan. 1956, when a slug of what was later found to be zinc wastes caused the final clarifiers to up-end. Since the symptoms of this upset were entirely new to plant personnel, and since there were absolutely no industrial wastes records for the city of Amarillo, it was nearly a month before the offending waste was identified, tracked down, stopped at its source, and a new activated sludge built up. This month-long shutdown cost the water reclamation plant about $5,000 in loss of revenue, overtime fees, laboratory work, and other necessary expenditures. Immediately following resumption of normal plant operation, steps were taken to prevent a recurrence of this type of upset.

Since the passage of an industrial waste ordinance and the appointment of the industrial waste technician, complete surveys have been conducted on several of the major industries. So far, it has not been necessary to invoke any of the penalties for noncompliance provided for in the ordinance. Nevertheless, a great amount of corrective action has been taken by offending industries.

One result of the industrial waste control program has been a reduction by almost one-fourth in the power requirements for the activated sludge plant. It is believed that this can be attributed partially to the elimination of oxygen-deficient chemical wastes and to the appreciable reduction in the raw-sewage BOD brought about by better control over food-processing wastes.

Average analyses of city water, plant influent, and plant effluent are compared in Table I with the water quality limits set out in the City-Com-

TABLE I.—Comparison of City Water, Raw Sewage, Treated Sewage, and Water Quality Standards Contained in the City-Company Agreement, mg/l

Constituent	City Water	Raw Sewage	Treated Sewage	City-Co. Contract
Calcium, as $CaCO_3$	97	108	104	—
Magnesium, as $CaCO_3$	152	188	192	—
Sodium	27	—	110	—
Iron	0.05	—	0.3	—
Alkalinity	255	359	310	—
Hardness	244	296	296	—
Silicate	56	—	79	—
Ammonia nitrogen	0	25	12	—
Nitrate nitrogen	1	0	5	—
Phosphate	0	30	20	—
Chloride	13	103	83	—
Sulfate	34	—	78	—
Dissolved solids	364	639	613	1,000
Suspended solids	0	255	10	25
BOD	0	300	15	25
COD	0	—	—	—
Chlorine residual	0.2	0	0.6	0.1
pH	—	7.5*	7.6*	6.8–9.0*

* pH units.

TABLE II.—Estimated Cost of Delivered, Reclaimed Water for Fiscal Year 1957

Rate of Delivery (mgd)	Cost (¢/1,000 gal)				
	Reclaimed Water				Fresh Water
	Amortization	Treatment	Transmission	Total	
1.5	8.08	5.54	3.60	17.22	18.00
3.0	4.04	5.54	2.72	12.30	18.00
4.5	2.69	5.54	2.75	10.98	18.00

pany agreement. Since the Company has found that some ammonia in the water is beneficial in boiler-makeup water, and that the total hardness should not exceed the methyl orange alkalinity, it is necessary to constantly adjust the rate of oxidation of the activated sludge to compensate for variations in the strength of the raw sewage in the attempt to produce the "best" industrial water.

Determining the Cost of Reclaimed Water

Because the price for reclaimed water depends directly on the cost of maintenance and operation of the sewage treatment plant, it is necessary to maintain an elaborate system of records at the sewage plant.

Probably the most difficult part of determining the water cost is the accurate division of material and labor expenditures among the three facilities operating under the maintenance and operation budget. These facilities are (a) the activated sludge plant for production of reclaimed water, (b) the pump station reservoir, meters, and transmission line for the reclaimed water, and (c) the old primary treatment plant. Material and labor accounting systems were started with the assumption that the industry would be willing to pay the following portions of cost of maintenance and operation:

1. Activated sludge plant—per cent of average daily production actually used for industrial purposes.
2. Reclaimed water pump station—total cost of maintenance and operation minus the cost for water used at the sewage plant for lawns, etc.
3. Old primary treatment plant—nothing (the City would have to operate this plant whether or not it were selling reclaimed effluent).

All labor expenditures are accounted for on labor sheets. At the end of each pay period, data from the individual sheets are summarized and a proportional labor cost for reclaimed water is assigned.

The complete cost of each maintenance and repair job performed is kept on job sheets. These sheets are then handled in a manner similar to that used for determining labor costs charged to water reclamation. The actual cost of materials used on jobs is obtained from a perpetual inventory system.

The aim of all of this record-keeping is to determine the proper figure to be inserted in the third column of Table II.

Conclusions

At Amarillo, municipal wastewater is transformed into a source of industrial water. This operation has been going on for four years and its feasibility and profitableness have been proved beyond doubt.

II. INDUSTRIAL PHASE

By Dean E. Alexander

Project Engineer, Texaco Inc., Amarillo, Tex.

Water is as important to a refinery as crude oil. Actually, a refinery uses more water than crude oil—two barrels for every barrel of crude oil processed and many refineries use as much as five barrels for every barrel of crude oil.

In the early 1950's, Texaco started expansion of its Amarillo refinery. Plans called for an initial water consumption of 1.5 mgd and a future demand of 4.5 mgd. At the time, consumption was only one-fifth of the anticipated 1.5-mgd demand and no additional supplies were available at the refinery site. There was, however, sufficient underground water in the surrounding area which could have been developed by Texaco, or developed by the city of Amarillo and sold to Texaco, but there were some disadvantages to either of these plans. Most important was the fact that the Company did not wish to enter the water producing business at a location removed from the refinery site. Also, there was no wish to burden the facilities of Amarillo which had been expanded quickly to take care of the rapid increase in population and industrial growth.

As a solution, sewage treatment plant effluent was selected as a source of water. As the consumption of drinking water increases, the availability of used water will increase rather than decrease, as would be the case if fresh water were used. It is also to be expected that the price of fresh water will increase as it becomes less available. The price of treated sewage may also increase, but only as labor and material prices increase, and not due to any scarcity factor. Considering the long-range availability and dependability of this source of water, the choice seems logical.

Water Treatment

In using this water some difficulties were anticipated, thus the design was kept as flexible as possible. Aside from the City's storage, the Company installed a reservoir with a capacity of approximately 10 mil gal. This was done because it was believed that additional storage time would improve the quality of the water. Actually, this has not been the case and under normal operations this reservoir is bypassed.

The water treatment equipment installed by Texaco is conventional in design and type, although oversize for present throughput. This oversizing is believed to be very important, for it has permitted operation to proceed with very few major treatment problems.

Makeup to cooling water is treated by the cold lime-alum process. The primary purpose of this treatment is not to soften, but to remove phosphates so as to prevent the production of tri-calcium phosphate sludge in hot sections of cooling equipment. Also, the cold lime-alum treatment reduces the silica content until it is now no longer troublesome, and it lowers magnesium hardness. One of the peculiarities of reclaimed water, and one which is believed to be true of most sewage effluents, is that calcium hardness cannot be reduced by cold lime treatment.

Hot lime and hot zeolite treatment is employed in treating boilerwater. Although the sludge formed in hot lime treatment is somewhat light, it has an adhesive quality which holds it together very well, and with oversize equipment a very clear effluent is obtained. No problems are encountered in hot zeolite treatment.

After further deaeration, this hot lime—hot zeolite treated water is a

TABLE III.—Typical Water Analysis, mg/l

Constituent	Sewage Effluent	Cold Process Water	Hot Process Water	Boiler Feedwater
Calcium, as $CaCO_3$	104	108	22	0
Magnesium, as $CaCO_3$	192	80	2	0
Iron	0.3	—	—	—
Copper	0.07	—	—	—
Ammonia nitrogen	12.5	—	—	—
Nitrate nitrogen	5	—	—	—
Phosphate	20	0	0	0
P. alkalinity	0	140	44	24
M.O. alkalinity	316	220	62	44
pH	7.6*	9.6*	9.4*	9.6*
Silica	79	38	10	7
Chlorides	83	—	—	—

* pH units.

very satisfactory makeup water for 250-psi boilers. After three years' operation, the boilers are in excellent condition. Condensate system corrosion is no longer a problem because of the 10 to 15 mg/l of ammonia in the steam, and predicted problems usually associated with high ammonia content have failed to materialize.

Experiences and Results

On only two occasions has serious foaming been encountered. However, the system is designed so that fresh water, in any proportion, can be used. An anti-foam agent was used in the boilers before the conversion to effluent, and this practice has been continued regardless of whether or not foaming is experienced. Foaming in cooling towers has never been serious enough to limit the use of this water for cooling.

The control of slime and algae growths has been much easier than anticipated. Continuous chlorination of cooling water has proved quite satisfactory. Short-term tests have indicated that there are probably a number of other algaecides that would also be satisfactory.

A typical analysis of the reclaimed wastewater together with typical analyses of the water coming from the water treatment units are shown in Table III.

In addition to the more common elements found in fresh water, there are no doubt numerous other organic and inorganic compounds found in the used water. Many may have no undesirable effect and some may be helpful. For instance, nitrates are believed to have some value as corrosion inhibitors in cooling water, and the use of nitrates to combat caustic embrittlement in boilers has been common practice for years. There are other compounds which might be harmful, although they are not present in sufficient quantity to cause trouble. Copper in solution will cause corrosion of iron; an increase in chlorides tends to increase corrosion; any increase in total dissolved solids will limit boiler concentrations.

Experience to date indicates there is nothing in the effluent from a well-operated activated sludge plant that would preclude its use as an industrial water.

TIPS AND QUIPS

Effluent Reuse

The National Council for Stream Improvement, Inc., reports that the Southland Paper Mills, Inc., Lufkin, Tex., is now treating solids-free groundwood machine waters by the activated sludge process. For several years this mill has successfully oxidized kraft pulp mill effluent by biological means. Eventually, Southland plans to re-use the treated groundwood effluent in the bleach plant and the pulp mill.

Cave-in

The Metropolitan St. Louis (Mo.) Sewer District recently had a complaint about a probable sewer stoppage. An emergency crew was dispatched and labored all day and night without success. The sewer was 18 in. in diameter and 23 ft below the alley surface.

The next day it was decided that digging was necessary. Crewmen removed the concrete pavement and were down about 6 ft into hard clay when the bottom of the trench collapsed. Fortunately, no one was hurt.

The cave-in was 35 ft long, 15 ft wide, and from 15 to 22 ft deep. The cave-in revealed another hazard—a brick foundation wall for a one-story dwelling was exposed.

To complicate repair work, quicksand was found at a depth of 21 ft. Vertical wood sheeting was driven and had to be left in place. The new sewer was laid in a concrete cradle.

Sludge Utilization

A recent newsletter of the New York Sewage and Industrial Wastes Association carried the following notice:

"'For many years we have been selling dried activated sewage sludge as a fertilizer and are interested in securing further supplies . . . we would appreciate buying this material in bulk carload lots and would also appreciate receiving a sample and an analysis and price per ton . . . we are prepared to make a yearly contract for any tonnage that is available.'—The Toronto Salt Works Ltd., 196 Eastern Ave., Toronto 2 B, Ont."

Big Pond

The city of Everett, Wash., has awarded a contract for what may be the largest raw sewage stabilization pond in the United States.

The pond will have a primary cell with a water surface area of 136 acres and a secondary cell of about 27 acres. The height of the dike forming the two cells is 7.5 ft and the liquid depth is 4 ft. The pond will treat combined sewage. A concrete building will be constructed at the site to house the laboratory and maintenance supplies. The low bid of $293,095 included the construction of 2,000 ft of 24-in. pipe, 2,000 ft of 39-in. pipe, and 900 ft of 48-in. pipe in addition to the pond construction cost.

De-inking Sludge *

De-inking plant sludge—material left when old magazines are reclaimed to make paper—may prove valuable in manufacturing light-weight bricks. Experiments now are under way in the Ceramics Department of the University of Washington to explore this possibility. The research is sponsored by Simpson Paper Company and the Lowell Brick Company, both of Everett, Wash. Simpson produces 42 tons of paper pulp per day from 70 tons of old

* From *Northwest Pulp & Paper News*, Apr.–May 1959.

magazines. This has reduced their use of raw wood by 84 cords per day, a conservation measure. In the process, inks, clay coating materials, and some small fibers are washed out. Disposing of this sludge has been difficult and has deterred further expansion of reclaiming operations. Experimentally, sludge has been used, in varying combinations, to make bricks at the adjoining Lowell plant. Some pilot-model bricks have been of much lighter weight than regular clay bricks. Encouraged by preliminary results, the two companies set up the research project hoping to unlock an economical process for utilizing de-inking sludge which at the same time would improve current waste disposal practices.

Ion Exchange

An 11-year index of *Amber-hi-lights*, a publication of the Resinous Products Division of Rohm and Haas Co., Philadelphia 5, Pa., is now available. The first 50 issues are covered in the index. Also included is an index to abstracts which have been published in the last 25 issues.

Disaster Averted *

Cleaning the Imhoff tank at Webster, S. Dak., was almost fatal to three men. The tank had been pumped down until only four or five feet of sludge remained. The first man to descend into the tank was overcome and so were two more who went to aid him. The fourth man called the fire department which resulted in the rescue of the other three.

Radioactive Wastes

A recent report in *The Sunday Star* (Washington, D. C.) states that commercial and military jet aircraft are picking up radioactive material in increasing amounts at the higher altitudes. Although the radiation does not penetrate the plane's exterior skin, it nevertheless causes a radioactive problem because when "a plane that has become radioactive is washed, the water is carried off into the sewer."

Dr. Abel Wolman of Johns Hopkins University is reported as noting "that the problem will grow as more and more high-flying aircraft are put into use."

The Radiological Health Division of the Public Health Service is studying the problem.

High Cost of Fishing

At the 7th Annual Pennsylvania Clean Streams Conference, Mr. D. F. Paddock, Pure Streams Chairman, Pennsylvania Federation of Sportsmen's Clubs, stated that the annual average expenditure of the State's 1,173,000 fishermen is $77. This amounts to $90 million each year. Mr. Paddock points out that a 4-per cent return on an investment of $2.25 billion would be required to accumulate this annual expenditure.

For all forms of water recreation the annual expenditure in Pennsylvania is about $180 million.

Sewer Specifications

The American Public Works Association has revised its earlier specifications for sewer construction. The new specifications, J1-58, sell for $2.00 and are the result of a review of many specifications currently in use by a variety of agencies and engineers.

The address of the APWA is: 1313 East 60th St., Chicago, Ill.

Live your life, do your work, and take your hat.

HENRY THOREAU

* From *The Clarifier*, newsletter of South Dakota Water and Sewage Works Conf.

Federation Affairs

THIRTY-SECOND ANNUAL MEETING PREVIEW

Statler Hilton Hotel, Dallas, Texas

Technical Sessions and Exhibits—Dallas Memorial Auditorium
October 12–15, 1959

★

HOST ASSOCIATION—TEXAS WATER AND SEWAGE WORKS ASSOCIATION

★

THE OFFICIAL PROGRAM

SUNDAY, OCTOBER 11

Afternoon

Early Registration—Ground Floor, Dallas Memorial Auditorium

MONDAY, OCTOBER 12

Morning

Registration—Ground Floor, Dallas Memorial Auditorium

Inspection of Exhibits—First Floor, Dallas Memorial Auditorium

Thirty-Second Annual Meeting Called to Order—
President W. D. Hatfield

Invocation—Uel Stephens, Chaplain, Texas Water and Sewage Works Association

Welcome to Dallas—Troy L. Satterwhite, Chairman, Texas Water and Sewage Works Association

Reports of Federation Officers

United States-Mexico Border Pollution Abatement Problems
Pedro J. Caballero, Jefe del Laboratorio de Agua, Mexico, D. F., and Keith Krause, Assistant Regional Engineer, USPHS, Dallas, Texas

Water Quality Control Considerations in Red River Compact
Moderator: Henry C. Beckman, U. S. Geological Survey, Rolla, Mo., Federal Representative on Compact
Participants: H. M. Crane, Sanitary Engineer, Oklahoma State Department of Health; D. F. Smallhorst, Director Water Pollution Control Division, Texas State Department of Health; Glen T. Kellogg, Chief Engineer and Director, Bureau of Sanitary Engineering, Arkansas State Board of Health; John E. Trygg, Director, Division of Public Health Engineering, Louisiana State Department of Health; and K. E. Biglane, Executive Secretary, Stream Pollution Control Commission of Louisiana

Afternoon

Water Resources as Viewed by a Federal Agency
Mark D. Hollis, Assistant Surgeon General and Chief Engineer, USPHS, Washington, D. C.

Water Resources as Viewed by an Industry
N. D. Griswold, Assistant General Manager, Texas Division, Dow Chemical Company, Freeport, Texas

Water Resources as Viewed by a State Agency
Milton P. Adams, Executive Secretary, Michigan Water Resources Commission, Lansing, Mich.

Control of Radioactive Pollution of the Animas River
E. C. Tsivoglou, M. Stein, and W. W. Towne, USPHS, Cincinnati, Ohio

TUESDAY, OCTOBER 13

Morning—Concurrent Sessions

DESIGN AND OPERATION SESSION

Design, Construction, and Operation of Sewer Outfalls in Estuarine and Tidal Waters
Frank L. Heaney, Sanitary Engineer, Fay Spofford and Thorndike, Boston, Mass.

Operating Experiences at Camden, N. J., Sewage Works
Vincent P. Brunick, Assistant Superintendent of Sewage, Camden, N. J.

The Operation and Maintenance of Gas Engines at the Santa Rosa Sewage Treatment Plant
Murray B. McKinnie, Superintendent, Sewage Treatment Works, Santa Rosa, Calif.

Design and Operation of the Louisville, Ky., Sewage Treatment Works
Frank A. Marston and Robert W. Muther, Jr., respectively Partner and Project Engineer, Metcalf and Eddy, Boston, Mass.

MANAGEMENT SESSION

Sewage Works Operations Management
Ben Benas, Purchaser, City and County of San Francisco; Walter B. Jones, Acting Superintendent, Bureau of Sewers and Sewage Treatment; and Keeno Fraschina, Acting Senior Engineer, Bureau of Sewers and Sewage Treatment, San Francisco, Calif.

Engineering Aspects of Financing Sewage Authority Projects
S. I. Zack, Vice-President and Director of Sanitary Division, Gannett Fleming Corddry and Carpenter, Inc., Harrisburg, Pa.

Sewerage and Industrial Waste Practices of the County Sanitation Districts of Los Angeles County
John D. Parkhurst, Assistant Chief Engineer, Los Angeles County Sanitation Districts, Los Angeles, Calif.

Insurance and Its Place in Sewage Works Management
Ralph E. Roderick, Partner, Cornell, Howland, Hayes and Merryfield, Engineers, Corvallis, Ore.

Noon

FEDERATION LUNCHEON

Water Resources of Texas

Col. J. T. Ellis, Jr., Administrative Assistant to Governor Price Daniel

Afternoon

CONCURRENT INSPECTION TRIPS

Inspection Trip A

The Dallas and Trinity River Authority Sewage Treatment Works

Inspection Trip B

Texas Instruments, Inc., Wastes Treatment Works

RESEARCH SYMPOSIUM

Food-Population Equilibria in Bench-Scale Bio-Oxidation Units

A. W. Busch, and Nugent Myrick, respectively Assistant Professor and Research Associate, Department of Civil Engineering, The Rice Institute, Houston, Texas

Flow Equations for Sewage Sludges

Vaughn C. Behn, Associate Professor of Civil Engineering, University of Delaware, Newark, Del.

The Colicidal and Colistatic Effects of Halogens in Sewage

Jack E. McKee, Department of Sanitary Engineering, California Institute of Technology, Pasadena, Calif.; Charles Brokaw, Department of Zoology, University of Minnesota, Minneapolis, Minn.; and Ronald T. McLaughlin, World Health Organization, Bangkok, Thailand

Oxygenation Efficiency in Full-Scale Controlled Aeration Tank

Philip F. Morgan and Jatinder K. Bewtra, respectively Professor of Sanitary Engineering and Research Assistant, State University of Iowa, Iowa City, Iowa

Disposal of Radioactive Wastes in Deep Geologic Formations

Warren J. Kaufman, Associate Professor of Sanitary Engineering, University of California, Berkeley, Calif.; James V. Kerrigan, Assistant Research Chemist, Sanitary Engineering Research Laboratory, University of California, Richmond, Calif.; and Ben B. Ewing, Associate Professor of Sanitary Engineering, University of Illinois, Urbana, Ill.

WEDNESDAY, OCTOBER 14

Breakfast—Laboratory Scientists' Breakfast

The Use of Chromatography in the Analysis of Industrial Waste Problems

Moderator: Robert S. Ingols, Professor of Applied Biology, Georgia Institute of Technology, Atlanta, Ga.

Panelists: A. M. Buswell, Research Professor, University of Florida, Gainesville, Fla.; T. E. Larson, Head, Chemical Section, Illinois State Water Survey, Urbana, Ill.; Werner N. Grune, Professor of Civil Engineering, Georgia Institute of Technology, Atlanta, Ga.

Morning—Concurrent Sessions

MAINTENANCE FORUM

TREATMENT PLANT MAINTENANCE PANEL—Leader, D. P. Scott, Deputy Commissioner of Works, Metropolitan Toronto, Ont., Canada

Comminutor Maintenance

N. S. Bubbis, General Manager, Greater Winnipeg Sanitary District, Winnipeg, Man., Canada

Measuring Devices Maintenance

R. D. Bargman, Assistant Chief Engineer, Sewage Treatment, and Assistant to the Director, Bureau of Sanitation, Los Angeles, Calif.; and Jack M. Betz, Senior Civil Engineer, Hyperion Treatment Plant, Los Angeles, Calif.

Paints and Painting

K. L. Mick, Chief Engineer and Superintendent, Minneapolis-St. Paul Sanitary District, St. Paul, Minn.

Digestion Tank Maintenance

D. P. Scott, Deputy Commissioner of Works, Metropolitan Toronto, Ont., Canada

SEWER MAINTENANCE PANEL—Leader, S. A. Garza, Superintendent, Sanitary Sewer Division, Water and Sewer Department, Austin, Texas

Maintenance Records of Lift Stations and Sewer Mains

Ernest M. Hamilton, Superintendent of Sewers, Boulder, Colo.

Personnel, Tools, and Equipment for Sanitary Sewer Maintenance

A. E. Holcomb, Assistant Sanitary Sewer Supervisor, Dallas, Texas

House Laterals

Morris N. Lipp, City Manager and City Engineer, City of Miami Beach, Fla.

INDUSTRIAL WASTES SESSION

Waste Control in a Large Wet Industry Located on a Small Water Course

Frank J. Coogan, Assistant to Division Industrial Engineer, Southern Craft Division, International Paper Company, Mobile, Ala.

Economies in Metal Finishing Waste Management at Appliance Park

C. M. Fair, Superintendent, Water Management and Waste Control, General Electric Company, Appliance Park, Louisville, Ky.

Control Problems Using ORP in Industrial Waste Treatment Processes

Glen E. Summers, Industrial Wastes Service Engineer, Boeing Airplane Company, Wichita, Kans.

Noon

INDUSTRIAL WASTES LUNCHEON

Industry's Viewpoint on Water Conservation and Water Pollution Abatement

T. A. Wilker, Plant Superintendent, Union Carbide and Chemicals Co., Texas City, Texas

Afternoon—Concurrent Sessions

UNIT PROCESSES

Sludge Filtration Process

E. H. Trubnick, Engineer, Komline-Sanderson Engineering Corporation, Peapack, N. J.

Thermal Principles of Drying and/or Incineration of Sewage Sludge

Claude A. Leet, Jr., Production Manager; C. W. Gordon, Manager; and R. G. Tucker, Combustion Engineering, Inc., Chicago, Ill.

Ultimate Sewage Sludge Disposal by Wet Oxidation

E. Hurwitz and W. A. Dundas, respectively Director of Laboratories and General Superintendent, Metropolitan Sanitary District of Greater Chicago, Chicago, Ill.

Hydraulic Load, Organic Load, and Efficiency in Trickling Filters

K. L. Schulze, Assistant Professor of Civil Engineering, Michigan State University, East Lansing, Mich.

COMBINED TREATMENT

Solving South Charleston's Waste Problems Through the Combined Approach

I. Background of the Combined Approach as Viewed by Industry

George P. Schrader, Project Engineer, Union Carbide Chemicals Company, South Charleston, W. Va.

II. The South Charleston Sewage Collection System and Treatment Works

J. K. Latham and J. W. Finney, Partners, Howard K. Bell, Consulting Engineers, Lexington, Ky.

Anaerobic Treatment of Combined Sewage and Fruit Canning Wastes at San Jose, California

John T. Norgaard, Sanitary Engineer, Brown and Caldwell, San Francisco, Calif.; Ronald Hicks, Chief Chemist, Auckland Metropolitan Drainage Board, Auckland, New Zealand; and Donald A. Reinsch, Sanitary Engineer, Brown and Caldwell, San Francisco, Calif.

Community Treatment Plant for Upper Potomac River

Richard Hazen, Partner, Hazen and Sawyer, New York, N. Y.

Evening

ANNUAL FEDERATION AWARDS DINNER AND DANCE

THURSDAY, OCTOBER 15

Morning—Concurrent Sessions

OPERATORS' FORUM

Pertinent Analyses for Sewage Treatment Control

W. N. Wells, Sewage Treatment Engineer, San Antonio, Texas, and G. P. Edwards, Professor of Sanitary Chemistry, New York University, New York, N. Y.

Effect of Storm Water Inflow and Infiltration on Sewage Treatment

David P. Backmeyer, Superintendent, Sewage Treatment Plant, Miami, Fla., and R. D. Leary, Chief Engineer and General Manager, Milwaukee Metropolitan Sewerage Commission, Milwaukee, Wis.

Air Pollution Control at Sewage Treatment Plants

C. E. Drummond, Associate Engineer, Wiedeman and Singleton, Atlanta, Ga.; Rolf Eliassen, Professor of Sanitary Engineering, and Clement A. Vath, Research Assistant, Massachusetts Institute of Technology, Cambridge, Mass.

Disposal of Dried Sludge as a Soil Conditioner

M. M. Cohn, Editorial Director, *Wastes Engineering* and *Water Works Engineering,* New York, N. Y.

INDUSTRIAL WASTES SESSION

Subsurface Disposal of Salt Water in East Texas Oil Field

W. S. Morris, Vice-President and General Manager, East Texas Salt Water Disposal Company, Kilgore, Texas

Marine Waste Disposal Systems

Erman A. Pearson, Associate Professor of Sanitary Engineering, University of California, Berkeley, Calif.

Forecasting Heat Loss in Ponds and Streams

C. J. Velz, Professor of Public Health Engineering and Chairman, Department of Environmental Health, and John J. Gannon, Associate Professor of Public Health Engineering, both of the School of Public Health, University of Michigan, Ann Arbor, Mich.

Pollution Abatement in the Sugar Cane Industry of Louisiana

Arthur G. Keller, and H. K. Huckabay, respectively Professor of Chemical Engineering and Graduate Assistant, Engineering Experiment Station, Louisiana State University, Baton Rouge, La.

TECHNICAL PROGRAM COMMENTS

The official program bespeaks the enormous and successful efforts put forth by the Program Committee under its able chairman, George E. Symons. Advances as well as new problems in the wastewater field have caused the program to be the biggest ever. This year another session has been added to bring the total to eleven. Every consideration has been given to the arrangement of the concurrent sessions to keep competition of subject matter to a minimum.

Again, the participants scheduled for the Maintenance Panels and the Operators' Forum are readying them-

selves for the lively discussions that always accompany these ever-popular sessions. Those attending these sessions are urged to come prepared to partake.

The Laboratory Scientists' Breakfast this year will have an industrial wastes flavor when the discussion of chromatographic methods gets underway.

Another session of unusual interest will be the one on combined disposal of industrial and domestic wastes. Whenever this topic is discussed new ideas are certain to emerge.

All technical sessions will be held in the Memorial Auditorium and those present will leave Dallas with the latest technical information on the collection and treatment of wastewaters.

OTHER FUNCTIONS

The entertainment program for Monday evening will start out in the Memorial Auditorium with a big Texas-style Chuck Wagon Barbecue (at minimum price). From Chuck Wagon victuals to Square Dancing is a natural step, and what could be more appropriate in Texas? Pack some cool clothing and comfortable shoes for this one. Later in the evening there will be a gala Theatre Party featuring top stage and TV stars. It adds up to a wonderful night of pure pleasure and, except for the Barbecue, your ticket is your registration badge.

The Federation Luncheon will be at noon on Tuesday. Col. J. T. Ellis, Jr., Administrative Assistant to Governor Price Daniel, will discuss "Water Resources of Texas."

Tuesday evening is an open night and the Local Host Committee stands ready to help you form your personal plans. If you want suggestions, these are the people to see.

A dinner meeting of the Loyal Order of the Boar is scheduled for 6:00 PM Tuesday. Arrangements have been made by W. A. Hardenbergh and J. J. Gilbert. Boars and guests may purchase tickets at the Local Host Committee Desk.

At noon on Wednesday there will be an Industrial Wastes Luncheon featuring T. A. Wilker, Plant Superintendent, Union Carbide Chemicals Co., Texas City, Texas, who will discuss "Industry's Viewpoint on Water Conservation and Water Pollution Abatement."

The Federation Awards Banquet and Dance will be held on Wednesday evening. Last year nearly 800 gathered together for this social high point of Federation Week. At the Banquet, Federation awards and honors will be presented and new officers formally introduced. This is to be followed by dancing. Dress is optional.

Spring-weight clothing is recommended for fall in Dallas.

LADIES' ENTERTAINMENT

The Ladies' Entertainment Committee has put together a program of activities designed to win the admiration of all.

On Monday, an early afternoon tea with favors and a special speaker has been arranged for the Southland Center in the heart of downtown Dallas.

Late Tuesday morning, the Ladies' Forum will be set up under the leadership of Dr. M. M. Cohn. The Forum is well remembered from last year and all ladies are urged to attend and participate.

At noon on Tuesday luncheon will be served in the Hospitality Room of the Memorial Auditorium. In the afternoon there will be cards and other games with favors and prizes.

Wednesday will be Fair Day. Chartered buses will whisk the ladies away for a day at the World's Largest State

Fair. The Women's Building at the Fair will be a main attraction and the ladies will be provided with a Dallas Day Key which will entitle them to special prices for outstanding entertainment features there. The Fair is housed in a 40-million dollar plant and on the fairgrounds are the extensive collections of the Dallas Historical Society and the Museum of Fine Arts.

Throughout the week, at scheduled times, coffee will be served in the Hospitality Room.

And ladies, don't tell your husbands, but—the Statler Hilton is one block from Nieman-Marcus.

TECHNICAL INSPECTIONS

Tuesday afternoon has been set aside for inspection trips. Those selecting Inspection Trip A will enjoy visits to the large trickling filter plant serving Dallas and the new plant of the Trinity River Authority. This latter plant will be about 95 per cent complete.

The average sewage flow to the Dallas plant is about 80 mgd. Twenty-four 176-ft trickling filters cover the landscape. The Trinity River plant also has trickling filters but large lagoons have been substituted for conventional secondary settling tanks.

Inspection Trip B will take in the waste treatment works at the manufacturing facilities of Texas Instruments, Inc., a large electronic equipment producer. Here ion exchange units and automatic acid neutralization equipment are utilized in the treatment of metal wastes from a variety of sources.

EXHIBITS

Members of the Water and Sewage Works Manufacturers Association will exhibit a varied line of equipment in the spacious quarters provided on the first floor of the Dallas Memorial Auditorium. This arrangement offers the only opportunity for a large group to view and obtain personal consultation with those having expert knowledge of the latest equipment offered for use in the wastewater field.

The following companies have engaged exhibit space:

Airkem, Inc.
American City Magazine
American Well Works
Armco Drainage & Metal Products, Inc.
B-I-F Industries, Inc.
Bird Machine Company
Burgess-Manning Company, Penn Instruments Division
Carter Company, Ralph B.
Chain Belt Company
Chicago Pump Company
Combustion Engineering, Inc., Raymond Division
DeZurik Corporation
Dorr-Oliver, Inc.
Dow Chemical Company
Eimco Corporation, Process Engineers, Inc. Division
Engineering News-Record Magazine
Fischer & Porter Company
Flexible Inc.
Foxboro Company
Gorman-Rupp Company
Hardinge Company, Inc.
Homestead Valve Manufacturing Company
Inertol Company, Inc.
Infilco Inc.
Jeffrey Manufacturing Company
Johns-Manville
Keasbey & Mattison Company
Komline-Sanderson Engineering Corporation
Lakeside Engineering Corporation
Link-Belt Company
Lock Joint Pipe Company
Marlow Pumps Division of Bell and Gossett Company

Nichols Engineering & Research Corporation
Pacific Flush Tank Company
Perry Austen Manufacturing Company
Public Works Magazine
Robinson Clay Product Company
Roots-Connersville Blower Division, Dresser Industries, Inc.
Simplex Valve & Meter Company, Subsidiary of Pfaudler Permutit, Inc.
Smith-Blair, Inc.
Smith & Loveless, Inc.
Stuart Corporation
Vapor Recovery Systems Company
W-K-M, Division of ACF Industries, Inc.
Walker Process Equipment Inc.
Wallace & Tiernan, Inc.
Wastes Engineering Magazine
Water & Sewage Works and Industrial Wastes Magazines
Waukesha Motor Company, Climax Engine Manufacturing Division
Wemco, Division of Western Machinery Company
Worthington Corporation
Yeomans Brothers Company

REGISTRATION INFORMATION

Dallas is on Central Standard time throughout the year

Registration facilities will be located on the second floor (ground floor) of the Auditorium from Sunday afternoon, October 11, through Wednesday, October 14. A preregistration plan has already been described to the full membership in a flyer. This plan has proved to be a real convenience to those who have taken advantage of it the past two years. Preregistering will enable each individual to pick up tickets and badges at the Registration Desk on arrival.

Those who do not preregister are urged to register promptly to avoid the Monday morning rush. On Sunday, the Registration Desk will be open from 1 to 5 PM, and Monday through Wednesday registration will be from 8:30 AM to 4:30 PM.

Men's registration at $14 includes admission to the technical sessions, the Monday night Theatre Party, and the Annual Awards Dinner and Dance on Wednesday evening. Separately, the registration fee (required for admission badges to the technical sessions) is $8 and the Wednesday Dinner and Dance combination is $6.

The ladies' entertainment fee of $14 includes the refreshments provided in the Hospitality Room, Monday afternoon tea at the Southland Center, the Monday evening entertainment following the Chuck Wagon Barbecue, the Tuesday Ladies Forum, Tuesday Luncheon in the Hospitality Room area, Tuesday afternoon card party, day at the fair on Wednesday, and the Wednesday evening Dinner and Dance. Separately, the tickets are $8 for the special ladies' events and $6 for the Annual Awards Dinner and Dance.

Individual tickets will be sold for the Monday Chuck Wagon Barbecue, the Federation Luncheon on Tuesday, the Tuesday afternoon inspection trips, the Laboratory Scientists' Breakfast on Wednesday, and the Industrial Wastes Luncheon on Wednesday.

PREREGISTRATION INFORMATION

The preregistration plan successfully offered for the past two years is being continued this year. The convenience of having the tickets and badges ready on arrival (during registration hours), thereby avoiding a wait in line, has been quite attractive. If not already done you are urged to mail your preregistration card now. Checks may be made to FSIWA and may be dated October 15, should this be desired.

Preregistration information, including the necessary registration card, was mailed to the entire membership late

in July. If additional registration cards and other information are needed, a request to the Federation of Sewage and Industrial Wastes Associations, 4435 Wisconsin Ave., N.W., Washington 16, D. C., will be honored by return mail.

Should a change of plans prevent you from attending the meeting, a full refund will be made if the badge and tickets are not claimed in Dallas. Tickets must be picked up a half business day prior to the Tuesday Luncheon, the Wednesday Luncheon, or the Wednesday Banquet, as the Federation makes guarantees for these functions. If tickets are claimed later there will be no assurance of a place at these functions; however, under these circumstances a refund is authorized.

To assure processing of preregistration cards before the meeting, the completed information must be received in the Federation office by Wednesday, October 7.

HOTEL ARRANGEMENTS

Requests for room reservations should be made as soon as possible to the Statler Hilton Hotel using the hotel reservation card enclosed with the preconvention flyer. If space is exhausted in the Statler Hilton, the requests will then go to nearby hotels. Space will be scarce the night of Oct. 10.

LOCAL ARRANGEMENTS COMMITTEE

The Local Arrangements Committee, with Henry J. Graeser as Special Chairman, includes the following subcommittees with their respective members:

Hotel Arrangements and Technical Sessions: Dave Smallhorst, Chairman; James D. Goff, R. E. Morris, Jr., and J. L. Robinson.

Finance: R. G. Ford, Chairman; Robert L. Nichols and E. F. Smith, Jr.

Registration: E. F. Smith, Jr., Chairman; Joe Dust and Charles K. Foster.

Entertainment: R. E. Morris, Jr., Chairman; Dave Smallhorst and Ed Morey.

Inspection Trips: Cecil Williams, Chairman; J. L. Wethered, A. E. Holcomb, Ben L. Grimes, W. S. Mahlie, Robert Nichols, and G. G. Rumley.

Local Host: Ben L. Grimes, Chairman; W. S. Van Netta, Cecil Williams, Jim Ohman, Sam Prator, J. W. Droke, W. W. McKinney, Bill Bach, and W. D. Bentley.

Ladies' Entertainment: Mrs. Henry J. Graeser, Chairman; Mrs. R. E. Morris, Jr., Mrs. Cecil Williams, Mrs. Ted Ferris, Mrs. Ed Morey, and Mrs. D. F. Smallhorst.

Reviews and Abstracts*

Chemical Oxygen Demand of Petrochemical Wastes—Modification of the Standard Catalytic Reflux Procedure. *Anal. Chem.*, 30, 1482 (1958).

This article recommends a modified procedure of the standard COD test to reduce the high chloride ion error. In this modification, the silver sulfate catalyst is not added until the acid chromate solution has oxidized the chlorides and driven the chlorine into the gaseous phase. This modification is shown to work very well for the hydrocarbon type waste for which it was developed.

R. S. INGOLS

Oxygen Transfer in Agitated Vessels. By D. H. PHILLIPS AND M. J. JOHNSON. *Ind. Eng. Chem.*, **51**, 1, 83 (Jan. 1959).

When sulfite was oxidized in an unsparged cylinder, all of the chemical reaction appeared to occur in a film of liquid adjacent to the interface. The absorption rate was limited by diffusion into the liquid film. When all the reaction occurred in the film, the transfer rate was independent of liquid agitation, and varied as the 1.5 power of the partial pressure of oxygen.

With sparging and violent agitation, the thickness of the liquid film was so reduced that practically all of the reaction seemed to occur in the bulk of the liquid rather than in the film. Here, the transfer rate was relatively independent of the reaction velocity constant, and was independent of the sulfite concentration over a wide range. The transfer rate in this system was proportional to the first power of the partial pressure of oxygen.

Since aerobic microorganisms rely primarily on the oxygen dissolved in the bulk of the liquid, the oxygen absorption rate with sulfite in an agitated, sparged system is the maximum rate at which oxygen becomes available to microorganisms under the same aeration conditions, neglecting the physical differences between the solutions.

For the sulfite oxidation method to be valid, practically all of the chemical reaction must occur in the bulk of the liquid, and the oxygen content of the bulk of the liquid must be negligible.

M. C. RAND

Agitation-Aeration in Submerged Fermentation. I. A Comparative Study of the Sulfite and Polarographic Methods for Measuring Oxygen Solution Rates in a Fermentor. By R. STEEL AND M. R. BRIERLEY. *Appl. Microbiol.*, **7**, 1, 51 (Jan. 1959).

Measurements of oxygen absorption by catalyzed sodium sulfite solution were compared with polarographic measurements of oxygen absorption in potassium chloride solution. At low agitator speeds the absorption coefficients were lower in the sulfite system, whereas at high agitator speeds the sulfite coefficients were higher than the polarographic values. The discrepancies are explained in terms of the differences in oxygen absorption mechanism in the two systems. The authors conclude that the sulfite system should not be used as a measure of the actual amount of oxygen transferred to a microbial culture.

M. C. RAND

Water Analysis. By L. L. THATCHER AND R. T. KISER. *Anal. Chem.*, **31**, 776 (1959).

A review of 269 articles published on the analysis of pure and polluted waters during the years 1957–1958.

R. S. INGOLS

* Please send to Federation headquarters all periodicals, bulletins, special reports, etc., which might be suitable for abstracting in THIS JOURNAL. Publications of public health departments, stream pollution control agencies, research organizations, and educational institutions are particularly desired. Address such material: Federation of Sewage and Industrial Wastes Assns., 4435 Wisconsin Ave., N.W., Washington 16, D. C.

A Toxicity Index for Industrial Wastes. By E. R. Hermann. *Ind. Eng. Chem.*, **51**, 84A (Apr. 1959).

Basic information is presented on the nature of response of organisms in the BOD dilution procedure toward a number of substances which are known to be toxic. The concept is dependent on the idea that a toxic material will cause a decreasing quantity of oxygen utilization with increasing quantity or concentration of the toxic substance. The points obtained by plotting oxygen utilization against the toxic matter concentration on a semilogarithmic scale produce a graph from which the 50-per cent depletion of oxygen in relation to the control may be read. This value is used as the "toxicity index." A table of a number of toxicity index values is included. A comprehensive discussion of the procedure and of some of the results is presented.

R. S. Ingols

Industrial Fungicides. By C. J. Wessell and W. M. Bejuk. *Ind. Eng. Chem.*, **51**, 52A (Apr. 1959).

This is a tabular compilation of the various uses for which fungicides are made by present day industrial users and the sources, with both the technical and commercial names of the compounds. This information can be useful for any sewage treatment plant receiving an industrial waste which may be interfering with the biological processes of treatment. With such a compilation the operator can know the type of compound that is used and may be emitted by an industry. Also it brings together the names of companies which make and distribute these various fungicides and their trade names. Some of these fungicides are useful in a treatment plant in the control of troublesome slime growth.

R. S. Ingols

An Electrode System for Measuring Dissolved Oxygen. By D. E. Carritt and J. W. Kanwisher. *Anal. Chem.*, **31**, 5 (1959).

In the past, polarographic devices using solid electrodes for oxygen tension determinations in various fluid systems have had very limited applicability because of electrode poisoning and a high temperature coefficient. The present device uses a plastic membrane to cover the electrodes and thus, reduces poisoning. It is temperature compensated by a thermistor in the electrode housing, and it functions satisfactorily in a wide variety of aqueous systems with continuous recording devices or as a completely portable instrument.

R. S. Ingols

Plant-Type Polarographic System for Determining Uranium in Radioactive Waste Streams. By G. L. Alkire, K. Koyama, K. J. Hahn, and C. E. Micholson. *Anal. Chem.*, **30**, 1912 (1958).

An industrial type polarographic system has been developed for the automatic determination of uranium in a radioactive waste stream. The equipment is designed for in-line use and records the uranium concentration in the range from 10^{-4} to 10^{-2}M every $7\frac{1}{2}$ min.

R. S. Ingols

BOOKS, REPORTS, PAMPHLETS

Atomic Energy Facts. U. S. Atomic Energy Comm., Washington, D. C. 216 pp. Price, $2.25, Supt. of Doc., Washington, D. C. (1957).

A handbook on nuclear operations in the United States for industrial management devoted to peaceful uses of atomic energy.

Manual of Septic-Tank Practice. U. S. Dept. of Health, Education, and Welfare, Public Health Service, Washington, D. C., Publ. No. 526. 85 pp. Price, $0.35 (1957).

Education Training and Utilization of Sanitary Engineers. National Academy of Sciences, National Research Council, Washington, D. C. 17 pp. (1957).

A report of the Conference on Education, Training, and Utilization of Sanitary Engineers held under the auspices of the Subcommittee on Personnel and Training of the Committee on Sanitary Engineering and Environment, Division of Medical Sciences, National Academy of Sciences, National Research Council, Washington, D. C., March 6–7, 1957. Discusses ways to encourage expanded education of sanitary engineers and recommends revised curricula.

Economic Applications of Atomic Energy—Power Generation and Agricultural Uses. United Nations, New York, N. Y. 108 pp. Price $0.50 (May 1957).

A comprehensive report of power generation and agricultural applications of atomic energy. Extensive use of graphical and tabular data.

New Sources of Energy and Economic Development—Solar Energy, Wind Energy, Tidal Energy, Geothermic Energy and Thermal Energy of the Seas. United Nations Department of Economic and Social Affairs, New York, N. Y. 149 pp. Price $1.25 (May 1957).

A detailed discussion of the uses of the energy sources listed in the title. Liberal use of photographs, tables, and graphs. 480 references.

Biological Problems in Water Pollution. Compiled and Edited by Clarence M. Tarzwell. U. S. Department of Health, Education, and Welfare, Public Health Service, Bureau of State Services, Division of Sanitary Engineering Services, Robert A. Taft Sanitary Engineering Center, Cincinnati, Ohio. 272 pp. (1957).

Transactions of a Seminar on Biological Problems in Water Pollution held at the Robert A. Taft Sanitary Engineering Center, April 23–27, 1956.

Landslides and Engineering Practice. Highway Research Board Special Report 29, Prepared by the Committee on Landslide Investigations. Edited by Edwin B. Eckel, Chairman. Washington, D. C. 232 pp. Price $6.00 (Jan. 1958).

Practical treatise on entire field of landslides, from causes to cures. Extensively illustrated.

Pollution Investigation in Northern Puget Sound. By Richard A. Wagner, Charles D. Ziebell, and Alfred Livingston, III. Washington Pollution Control Commission, Olympia, Wash. Technical Bulletin No. 22, 27 pp. (Summer 1957).

A technical study of prevailing Puget Sound water conditions as influenced by the discharge of municipal and industrial wastes.

The Homebuilders Guide to Effective Sewage Disposal. Yeomans Brothers Company, Melrose Park, Ill. 40 pp. (1958).

A non-technical primer on sewage pumping and treatment aimed at builders and municipal authorities whose interests are in communities of less than 1,500 population.

An Outline of Modern Water Treatment Equipment. The Permutit Company, New York, N. Y. 9 pp. (1958).

An illustrated, condensed, and simplified description of water treatment equipment.

10th Annual Report. New England Interstate Water Pollution Control Commission, Boston, Mass. 28 pp. (1957).

Third Annual Report for the Year Ended 15th May, 1957. Tweed River Purification Board, Edinburgh, Scotland. 28 pp. (1957).

Concrete Pressure Pipe Laying Instructions. Price Brothers Company, Dayton, Ohio. 16 pp. (1957).

Pocket manual describing step-by-step procedure for laying concrete pipe.

Waste Treatment and Disposal Aspects to Development of California's Pulp and Paper Resources. State Water Pollution Control Board, Sacramento, Calif. Publication No. 17, 102 pp. (1957).

A cooperative study by a number of agencies and individuals reviewing the major problems confronting the expanding pulp industry in California. 58 references.

Wood Tanks Reference and Data Handbook. National Wood Tank Institute, Chicago, Ill. 28 pp.

Varied information on wood tanks, including linings, installation, and care and maintenance.

Engineering Information on Venturi Meter Tubes. Technical Bulletin 110-P1, 29 pp.; and **Engineering Information on Dall Flow Tubes.** Technical Bulletin 115-L3C, 18 pp. Builders-Providence, Inc., Providence, R. I.

Third Report on the Study of Waste Water Reclamation and Utilization. State Water Pollution Control Board, Sacramento, Calif. Publication No. 18, 102 pp. (1957).

The concluding report in the thorough and valuable series of wastewater reclamation studies sponsored by the State Board of Health.

Sixteenth Semi-Annual Report, The Balcones Research Center. The University of Texas, Austin, Tex. 146 pp. (1957).

Report of research activities for period of June 20 to Dec. 20, 1957.

Investigation of Pollution in Port Angeles Area. By Donald R. Peterson and Charles V. Gibbs, Washington Pollution Control Commission, Olympia, Wash. Technical Bulletin No. 23, 35 pp. (Summer 1957).

Teamwork on the Potomac. Interstate Commission on the Potomac River Basin, Washington, D. C. 68 pp. (1958).

An attractive, illustrated story of the Commission's history and activities.

Sanitary Engineering Education in Peru. Department of Sanitary Engineering, School of Public Health, University of North Carolina, Chapel Hill, N. C. 51 pp. (1958).

Description of a cooperative technical program with Peru.

A Re-Investigation of Pollution in the Lower Chehalis River and Grays Harbor (1956–1957). By Donald R. Peterson, Richard A. Wagner, and Alfred Livingston, III. Washington Pollution Control Commission, Olympia, Wash. Technical Bulletin No. 21, 51 pp. (Summer 1957).

Survey report, data, and recommendations.

Source Materials on Water Pollution Control. U. S. Dept. of Health, Education, and Welfare, Public Health Service, Washington, D. C. Public Health Bibliography Series No. 22, Publication No. 243. 24 pp. (1958).

A list of reports, publications, reprints, films, etc. available from the Public Health Service.

Sewage and Water Works Construction 1957. By William H. Abbott, Kenneth H. Jenkins, and Elsie M. Gibson, U. S. Department of Health, Education, and Welfare, Public Health Service, Washington, D. C. Bulletin 608, 15 pp. (1958).

Compilation of construction contract awards for municipalities, special districts, other governmental bodies, institutions, resorts, recreational centers, and a few industries for sewage treatment works, collecting sewers, waterworks, and combinations of the previous group.

The Story of Clay Pipe Yesterday Today Tomorrow. National Clay Pipe Manufacturers, Inc., Washington, D. C. 48 pp. (1958).

Attractive and interesting history of clay pipe. Extensive illustrations.

1957 Proceedings of the Oklahoma Water, Sewage and Industrial Wastes Association. I. Industrial Wastes Conference. II. Water and Sewage Short Course. H. M. Crane, Sec.-Treas., 3400 Northeastern, Oklahoma City 5, Okla. 78 pp. (1958).

Compilation of the papers presented at the 1957 meetings.

L. I. A. Formula 9-2. A Single Red Lead Primer for Rusted, Weathered or New Galvanized Steel. Red Lead Technical Letter No. 13, Lead Industries Assn., New York, N. Y. 3 pp. (1958).

Grounds Maintenance Handbook. By Herbert S. Conover, F. W. Dodge Corp., New York, N. Y. 503 pp. Price $10.75 (1958).

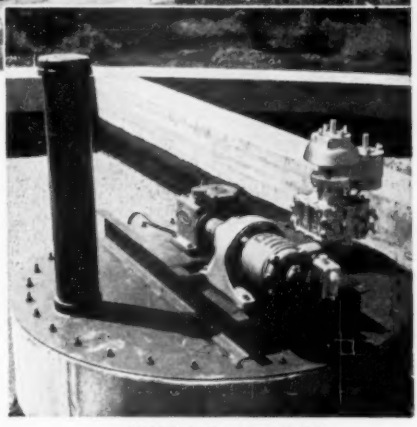
Comprehensive guide for landscaping and maintenance of public, semi-public, industrial, and commercial grounds. 10 chapters, illustrated.

Annual Report of the Scientific Adviser for the Year 1957. London County Council Public Health Department, Scientific Branch, The County Hall, Westminster Bridge, S.E. 1. Publication No. 4012. 44 pp. Price 1s. 3d. Postage extra (1958).

Report on the Scientific Branch of the Public Health Department. Includes report and data from sewage treatment works and direct discharge data.

BIOSORPTION® Activated Sludge Plant
Neillsville, Wisconsin

Consulting Engineers
Davy Engineering Co., Inc
La Crosse, Wisconsin



"VAREC" Fig. No. 5800C
Pressure Relief and Vacuum Breaker
Valve installed on INFILCO unit.

4 SUPERIOR FEATURES

"Varec"

PRESSURE RELIEF and VACUUM BREAKER VALVE with FLAME ARRESTER

FIG. No. 5800C

1. The multi-plate Flame Arrester bank has larger area than competitive units of same size.

2. Much more flow per minute than same size competitive equipment, due to less capillarity and friction in the Flame Arrester passageways; streamlining and expanding passageways of Pressure Relief and Vacuum Breaker Valve.

3. Easy to clean. Just loosen frame holding Flame Arrester plates together – plates separate to permit easy cleaning with distillate, chemical solution or wire brush.

4. All aluminum construction makes "VAREC" Pressure Relief and Vacuum Breaker Valve corrosion resistant. Lighter weight facilitates installation.

The flame arresting element is identical to that listed by Underwriter's Laboratories and approved by Associated Factory Mutuals Laboratories for use on oil storage tanks on which hazard is considerably greater than that generally encountered in sewage treatment plants.

Send for "VAREC" Catalog S-3 today.

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THE VAPOR RECOVERY SYSTEMS COMPANY

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32nd Annual Meeting

FEDERATION OF SEWAGE AND INDUSTRIAL WASTES ASSOCIATIONS

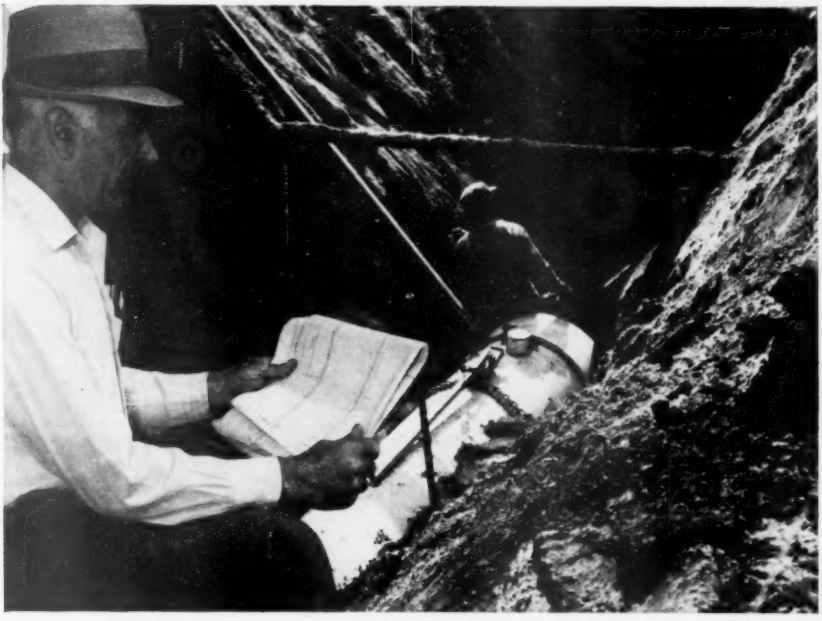
HOST ASSOCIATION — THE TEXAS WATER and SEWAGE WORKS ASSOCIATION

STATLER HILTON HOTEL

DALLAS MEMORIAL AUDITORIUM

Dallas, Texas

October 12-15, 1959



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...with Transite Sewer Pipe

says Anthony Garcia, President
Allerton Construction Co., New York

"In my eighteen years of installing Transite sewer mains and house laterals, I have never had a 'comeback' because of line failures. Most of the installations have been 100% under water. Therefore, tight joints that stay tight are absolutely essential! For these reasons Transite has always been my choice for sewer line service. I never worry about passing leakage or infiltration tests. I play it safe—with Transite."

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NEW BASIC DESIGN ADVANCES IN

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- EJECTOR STATIONS
- EJECTORS

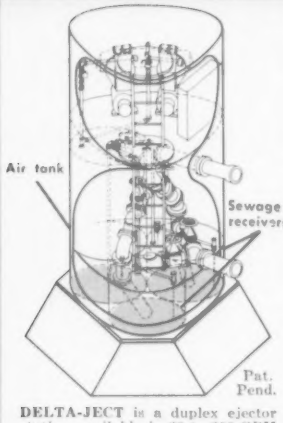
TEX-VIT Packaged Pump Station
New Design Means Better Operation

Flexible Coupling between motor and pump means extra rugged performance . . . four ball bearings instead of the two ordinarily used where pump and motor have common shaft. Pump, motor, shafts, or bearings can be replaced with standard off-the-shelf components. **New Direct Pressure Controls,** eliminating need for air compressor or actuating float, are actuated by changes in wet well sewage level. **Heavy Steel Shell** is watertight and protected against corrosion by special epoxy coating and magnesium anodes. Air inlet and outlet are at opposite sides of the station to provide maximum protection against short circuiting. Large blower provides complete air change every 60 seconds. Available in 30 to 4,000 GPM capacities. **Write for Bulletin No. PS-60.**

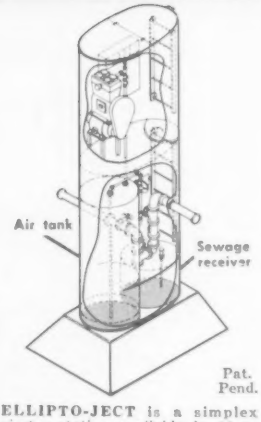
DELTA-JECT and ELLIPTO-JECT PACKAGED EJECTOR STATIONS

Exclusive Shell-Within-Shell Design Gives You —

- double protection against corrosion
- simplified maintenance with separate and replacable air tanks and sewage pots



DELTA-JECT is a duplex ejector station available in 30 to 200 GPM capacities. **Shell-within-shell** design provides maximum protection for air storage tank, sewage receivers and other components. All TEX-VIT Lift Stations are protected against corrosion with special epoxy coating and magnesium anodes. **Write for Bulletin No. DJ-60.**



ELLIPTO-JECT is a simplex ejector station available in 30 to 200 GPM capacities. Air storage tank, sewage receiver, fully wired controls and other components are enclosed in heavy steel outer shell. Air storage tanks in both simplex and duplex stations are pressure-tested to 200 psi. **Write for Bulletin No. EJ-60.**

TEX-VIT EJECT-ALL Pneumatic Ejector

These versatile Tex-Vit Ejectors are made in a wide variety of sizes (20 to 600 GPM) and component combinations to meet your specific installation requirements. Receiver pot, motor and compressor are shipped as a unit, with all electrical controls completely wired. The EJECT-ALL can also be supplied for remote installation where air is provided from air storage tanks or a central plant system. **Write for Bulletin No. EA-59.**

TEX-VIT Lift Stations, Ejectors and other products are manufactured to highest quality standards and are fully tested before shipment. They are backed by more than half century of experience in manufacturing materials for the sewer construction industry. Write for detailed specification data.

Only the finest components go into TEX-VIT Lift Stations and Ejectors. All models guaranteed for one full year from date of shipment from factory.

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INERTOL PAINTS PROTECT

MULTI-MILLION-DOLLAR MIAMI PLANT

Partial view of new Sewage Treatment Plant, City of Miami, Florida . . . buildings, tanks, equipment . . . protected with Inertol Paints.

On Virginia Key, three miles off the Florida mainland, stands Miami's new $10-million sewage treatment plant, heart of the new $27-million sewerage system. To protect this costly installation against the ravages of corrosion, fumes, condensation, salt air, heat and humidity, rugged Inertol coatings were specified (Consulting Engineers: Metcalf and Eddy, Boston, Massachusetts).

Buildings, the four 105′-diameter digesters, the towering chimney structure and other surfaces are protected economically and efficiently with *Ramuc® Masonry Paint.* Thousands more square feet of area of this 47-MGD plant are guarded with other corrosion-resistant, attractive Inertol coatings.

Buy Inertol paints direct from the manufacturer. Shipment within three days from our plant, or from nearby warehouse stocks. Write for free booklet S-754, "Principal Types of Protective Coatings."

SPECIFICATIONS FOR RAMUC MASONRY PAINT

A chlorinated natural rubber-base paint in color. Flat finish. For exterior above-grade masonry. Unaffected by masonry lime. Highly weather- and fume-resistant. No mottling.

Colors: Color Chart 563.

No. of coats: Two (if semi-gloss finish desired, specify semi-gloss type for top coat).

Coverage: 150-250 sq. ft. per gal. per coat, depending on surface texture.

Approx. mil thickness per coat: 1.5.

Drying Time: 24 hours.

Primer: None. However, to minimize efflorescence, specify one coat of Pluvol* as primer.

Thinners: Inertol Thinner 2000-A for brushing; 2000, for spraying.

Application: Brushing: As furnished. Spraying: First coat must be brushed. For spraying, add sufficient Thinner 2000 (10-15%).

*Registered Trademark. *Write for information on Pluvol, invisible silicone water-repellent.*

A complete line of quality coatings for sewage, industrial wastes and water plants.

INERTOL CO., INC.

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here's what "out of sight out of mind" does to a water main

"Out of sight—out of mind" can be a mighty expensive philosophy in any water distribution system. The above unretouched photograph proves this point. It shows a badly tuberculated *eight inch* main whose *inside diameter was reduced to an average of almost 4.5 inches.* Resultant higher pumping costs with reduced pressure and carrying capacity make it costly to tolerate such conditions. That is why the savings effected in reduced pumping costs frequently pay for the *low cost* of National water main cleaning.

Since there's never a charge or obligation to inspect your mains, *call National now!*

Call in National today!

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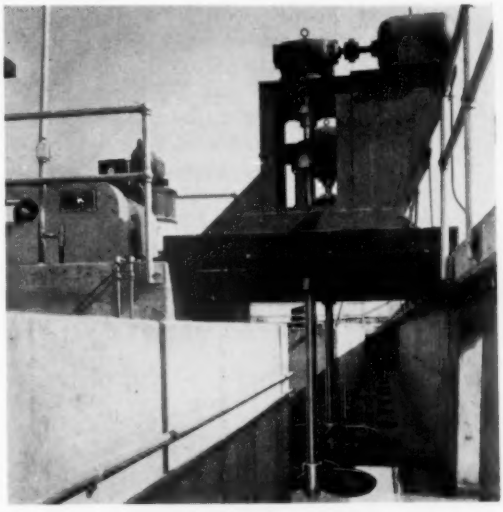
WHICH MIXING EQUIPMENT

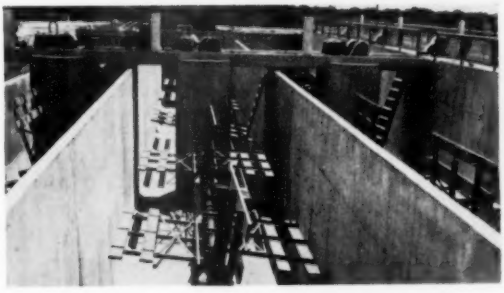
provides most efficient flocculation?

LINK-BELT's combination of flash and straightline mixers assures chemical savings of 30 to 40% . . . increases filter runs by 50% . . . decreases wash water demands

FLASH MIXERS PROVIDE RAPID, THOROUGH MIXING of chemicals with water, sewage or industrial liquids. They consist of a constant-speed motor directly connected to a quiet-operating worm gear reducer. This drive, mounted on a pedestal, is connected to a vertical propeller shaft so mounted that *underwater bearings are not required.* Load and thrust of the propeller shaft are taken up by bearings in the pedestal so these forces do not act on the reducer bearings. This efficient design assures long life and trouble-free operation. The propeller itself is an iron casting designed for high mixing efficiency with low horsepower requirements. Link-Belt flash mixers may be installed in concrete, steel or wood tanks by mounting on a steel or concrete platform spanning the tank walls.



STRAIGHTLINE MIXERS PROVIDE GENTLE SLOW MIXING to build up maximum size floc. These mixers consist of a number of sections, each made of a horizontal solid steel shaft carrying steel angle arms on which redwood paddles are mounted. The paddle shaft is driven by a chain drive from a Link-Belt Electrofluid drive coupled to a Link-Belt P.I.V. variable speed drive. The solid steel paddle shaft, with rigid compression couplings insuring perfect shaft alignment, turns in special babbitted bearings with water lubrication grooves. These bearings eliminate grease contamination of the water and prevent breakdown that may be caused by failure to provide proper lubrication. Use of redwood for paddles eliminates painting maintenance. Link-Belt makes a complete line of these mixers. Size and shape can be adapted to suit local requirements.



The mixers shown above are part of the broad line of Link-Belt sanitary engineering equipment. Get in touch with the Link-Belt office nearest you. Our sanitary engineers will be glad to work with your engineers, chemists and consultants . . . help you get the finest in modern treatment methods. Or write for your copy of Equipment for Chemical Flocculation Book 2442.

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LINK-BELT COMPANY: Executive Offices, Prudential Plaza, Chicago 1. Sanitary Engineering Regional Offices—Colmar, Pa., Chicago 9, Kansas City 8, Mo., San Francisco 24. Sales Offices in All Principal Cities. Export Office, New York 7. Representatives Throughout the World. 10,011

See our exhibit, Federation of Sewage and Industrial Wastes Assns., Memorial Auditorium, Dallas, October 11-15.

Equipment and Supply Lines

Pump Movie—A 23 min, 16-mm color movie shows the design and operating characteristics of the Wemco Torque-flow pump. Showings can be scheduled through the Torque-Flow Division, Western Machinery Company, 650 Fifth St., San Francisco 7, Calif.

Shop Phone Booth—An acoustically conditioned intercom booth (Figure 2) which is reported to cut noise levels by as much as 50 per cent has been placed on the market. The steel-constructed unit contains a perforated steel interior placed over sound absorbing material which is built into the walls and top.

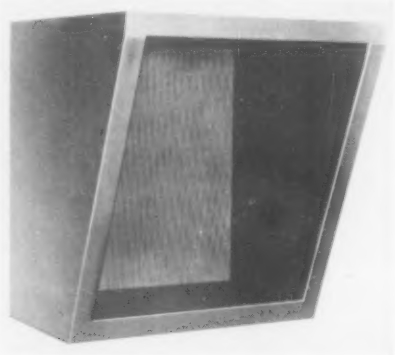


FIGURE 2.—Intercom booth.

Sewer Connections—A reference chart is now available showing the most efficient way of connecting asbestos-cement pipe to other pipe. Copies can be obtained by writing to Keasbey-Mattison Company, Ambler, Pa.

First Aid Kits—A new line of heavy-duty first aid kits designed to facilitate emergency treatment through use of unit-wrapped items, boldly labeled and arranged for immediate recognition and access, has been announced. Each kit has a facsimile index on the inside of the case lid which shows at a glance the exact location of all items and gives concise instructions for their use. The index also serves as a positive inventory control. The kits come in sizes of 10, 16, 24, and 36 units.—Bulletin 305, General Scientific Equipment Co., 7516 Limekiln Pike, Philadelphia 50, Pa.

Electric Motors—To help maintenance men save time and needless procedures in installing, inspecting, and servicing its Verticlosed pump motors, U. S. Electrical Motors, Inc., P. O. Box 2058, Los Angeles 54, Calif., has published an illustrated and charted instruction manual. The new manual is available on request.

Flow Measurements—Standard throats and capacities for Dall flow tubes and Venturi tubes and nozzles are given in Bulletin 100-PG.—Builders-Providence, Inc., 345 Harris Ave., Providence, R. I.

Clarifier—A new type of peripheral-feed circular clarifier (Figure 3) is now on the market. The manufacturer reports that the tank overcomes many of the apparent disadvantages of a conventional circular tank. Bulletin 315-9A1 describes the Rex Rim-Flow Clarifier manufactured by the Chain Belt Company, Milwaukee 1, Wis.

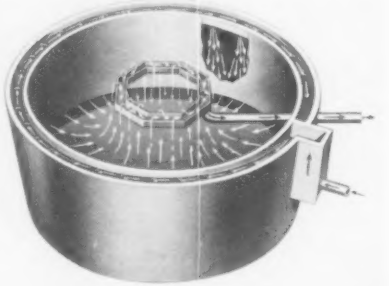
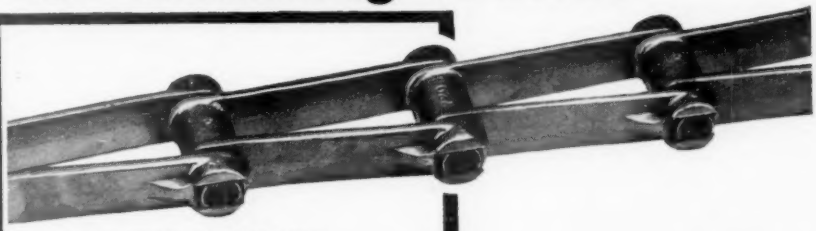


FIGURE 3.—Cutaway of Rex Rim-Flow Clarifier.

Webster CHAIN for Handling Wastes

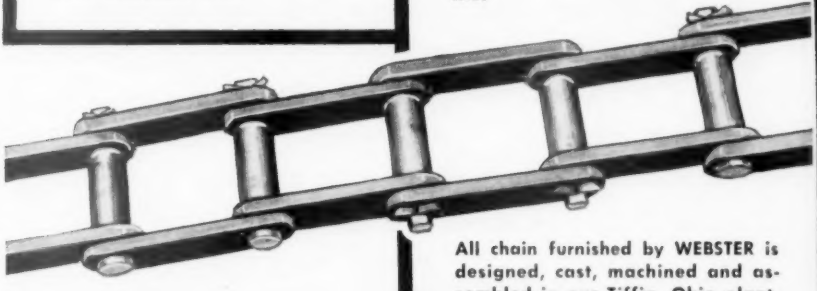


No. 720-S CHAIN

Designed especially for straight-line sludge and grit collectors, where long economical service is important. Pin and cotter construction. Pins have "T" heads securely fitted between lugs cast on side bars. This design prevents the pins from turning in the side bars, thereby distributing the wear over a large area in the barrels of the links. Available in malleable iron or Duramal which is approximately 20% stronger than malleable iron.

No. 111-N CHAIN

Designed for handling abrasive materials such as encountered in grit collectors. The barrels of the links are eliptical in shape to provide more material at point of greatest wear. This feature, together with the close-fitting joints, steel coupler links, and stationary steel pins provide maximum performance, sustained accuracy of pitch, and exceptionally long life.



All chain furnished by WEBSTER is designed, cast, machined and assembled in our Tiffin, Ohio plant.

Webster MANUFACTURING, INC.

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Offices in all Principal Cities

Proceedings of Member Associations

ARIZONA SEWAGE AND WATER WORKS ASSOCIATION

The Arizona Sewage and Water Works Association held its annual conference at the Hiway House Hotel, Phoenix, Ariz., Apr. 16–18, 1959. Over 350 members and their wives enjoyed the two and one-half day session. Guests included: W. D. Hatfield, President, Federation of Sewage and Industrial Wastes Associations; Raymond J. Faust, Executive Assistant Secretary, American Water Works Association; and James B. Corey, Director of Water Works Advancement, American Water Works Association. The kick-off luncheon on Thursday included an address of welcome by Mayor Jack Williams of Phoenix.

At the technical session, one of the most interesting papers was "Sewage Treatment for Hoover Dam in a Tunnel," by R. R. Kennedy, Consulting Engineer, San Francisco, Calif. Another outstanding paper was "Special Assessment Districts—The Contractor's Viewpoint," by Vic Fumetti, Sr., Engineer, Utilities Division, J. H. Welsh & Son Contracting Co., Phoenix, Ariz. All of the technical papers given will be reproduced in the Association's Annual Bulletin.

Fourteen safety awards were presented to private and municipal water utilities. In addition, safety awards for sewage installations were presented for the first time. During 1959, the Association's voluntary certification

(*Continued on page 394a*)

specialists

★ Sewer and Pipe Cleaning Equipment

★ Sewer Rods ★ Sectional Steel Rods

★ Complete Sewer Cleaning Machines

★ Braces and Guides

★ Buckets, Root Cutters, Drag Tools

Save the cost of experimenting. Consult Stewart for any problem in the specialized field of pipe cleaning.

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program for sewage and water works operators was inaugurated through the cooperation of the Arizona Department of Health. Also, the Association sponsored a correspondence course for sewage and water works operators. It was very encouraging to know that at least 17 of the 35 operators present at the Operators Round-up Session had qualified for the written examination which leads to certification.

The following officers were elected to serve for the year 1959–60:

President: Harry C. Bigglestone, Phoenix.

1st Vice-President: R. E. Polenske, Phoenix.

2nd Vice-President: Stanford I. Roth, Phoenix.

Secretary-Treasurer: A. D. Cox, Phoenix.

A. D. Cox
Secretary-Treasurer

UTAH SEWAGE AND INDUSTRIAL WASTES ASSOCIATION

The Utah Sewage and Industrial Wastes Association held its 2nd Annual Meeting at the University of Utah, Salt Lake City, Feb. 3, 1959. The meeting was held in conjunction with the Annual Water and Sewage Works School. The attendance was close to 180.

Featured presentations of interest to wastewater personnel included:

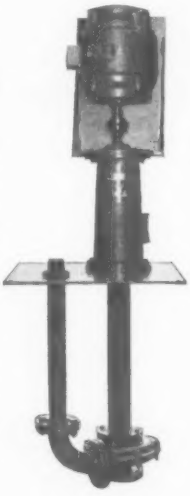
"Chlorination of Sewage Wastes," by George C. White, Division Manager, Wallace and Tiernan Inc., San Francisco, Calif.

"New Methods for Joining Sewer Pipe," by Rod T. Antrim, Field Engineer, Pacific Coast Clay Products Institute, Redondo Beach, Calif.

"Heating Sludge Digesters," by Calvin K. Sudweeks, Sanitary Engineer,

(*Continued on page 396a*)

This NAGLE PUMP is a "relief" around Sewage Treatment Plants!



This Nagle type "CWO-C" vertical shaft sewage sludge pump is a "relief" to sewage plant engineers because it gives trouble-free service and is easy to maintain, all parts being readily accessible.

It has a non-clogging impeller, designed specifically to handle sludge or abrasive slurries. All parts in contact with material being pumped are of abrasion resistant alloy. No bearings below the floor plate—no rubbing contact between revolving and stationary parts below this level.

Available in sizes from 1" to 16", capacities to 8000 GPM, and heads in some cases up to 230'. The type "CDO-C" is similar, but is for dry pit operation.

Nagle pumps available for handling raw and digested sludge, filter bed sand transfer, grit pumping, chemical pumping and sump pumping.

SALES REPRESENTATIVES IN PRINCIPAL CITIES

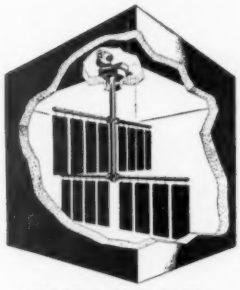
NAGLE PUMPS

NAGLE PUMPS, INC.
1210 CENTER AVE., CHICAGO HEIGHTS, ILL.

PUMPS FOR ABRASIVE AND CORROSIVE APPLICATIONS

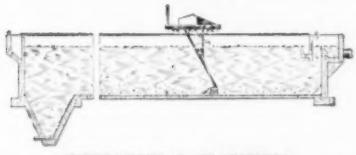
Send for NAGLE PUMP SELECTOR

WATER, SEWAGE AND TRADE-WASTE TREATING EQUIPMENT



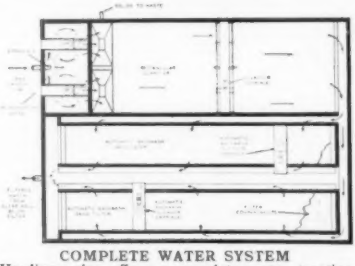
FLOCCULATION UNITS

Hardinge Flocculation Units are designed to impart the gentle stirring action required for controlled conditioning, featuring variable-speed drive and suspension of all submerged parts from top of tank.



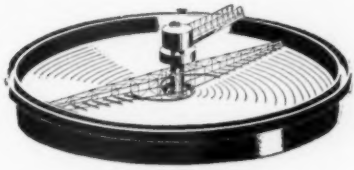
RECTANGULAR CLARIFIERS

Especially suited for limited spaces or where sludge delivery is desired at one end of the tank. A traveling scraper and skimmer carriage removes settled solids from the tank bottom and scum from the top.



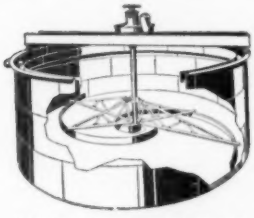
COMPLETE WATER SYSTEM

Hardinge also offers a complete water treating unit, combining flocculation equipment, clarifiers and filters in one, common-wall system, using modular construction.



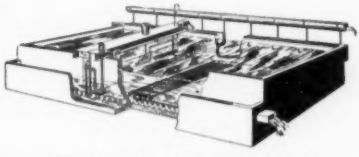
CIRCULAR CLARIFIERS

Hardinge Circular Clarifiers are available in sizes up to 200′ diameter, either center-column or beam supported for steel, concrete, wood or tile tanks. Sludge scrapers remove settled solids rapidly through central underflow discharge.



"AUTO-RAISE" THICKENERS

For removal of fine suspended solids from supply water, waste water and sewage. "Auto-Raise" mechanism prevents scraper breakage. Manual or power raise supplements "Auto-Raise." Replaceable ring-type ball bearing support for rotating mechanism. Spiral rakes for maximum underflow density.



AUTOMATIC BACKWASH FILTERS

For high removal of non-settling or slow settling suspended matter. Self-cleaning sand bed. No shut-down necessary for backwashing. Traveling backwash mechanism. "It cleans itself while filtering."

Write for information. Ask for Bulletin 35-D-16.

See our display in booth No. 78 at the F.S.I.W.A. show in Dallas, Oct. 11-15.

HARDINGE
COMPANY, INCORPORATED

YORK, PENNSYLVANIA • 240 Arch St. • Main Office and Works

New York • Toronto • Chicago • Hibbing • Houston • Salt Lake City • San Francisco • Birmingham • Jacksonville Beach

Utah State Department of Health, Salt Lake City, Utah.

At the business meeting the following officers were elected for the year 1959:

President: Lyle S. Ford, Salt Lake City.
Vice-President: Emil Meyer, Salt Lake City.
Secretary-Treasurer: Howard M. Hurst, Salt Lake City.

HOWARD M. HURST
Secretary-Treasurer

OKLAHOMA WATER, SEWAGE AND INDUSTRIAL WASTES ASSOCIATION

Water and Sewage Short Course

The 32nd Oklahoma Water and Sewage Short Course was held at Oklahoma State University, Stillwater, Okla., Nov. 17–21, 1958.

During the first part of the 5-day meeting sewage works fundamentals were stressed. In the latter part of the course technical papers were presented on the following topics: personnel problems, Oklahoma water resources, sludge dewatering, total oxidation treatment, plant safety, and municipal financing.

The Annual Meeting of the Oklahoma Water, Sewage and Industrial Wastes Association was held in conjunction with the Water and Sewage Short Course.

The following officers were elected:

President: Calvin T. Grant, Norman.
Vice-President: John Downing, Oklahoma City.
Director: Lester L. Settle, Oklahoma City.
Secretary-Treasurer: H. M. Crane, Oklahoma City.

H. M. CRANE
Secretary-Treasurer

(*Continued on page 398a*)

SNOW GATES for Sewage Treatment Plants

All types of cast iron gates manufactured in either square or circular opening in sizes up to and including 72 inches.

ALL SNOW GATES and Lifts are "Parkerized" for protection against rust and corrosion.

Over 40 years continuous service to the industry.

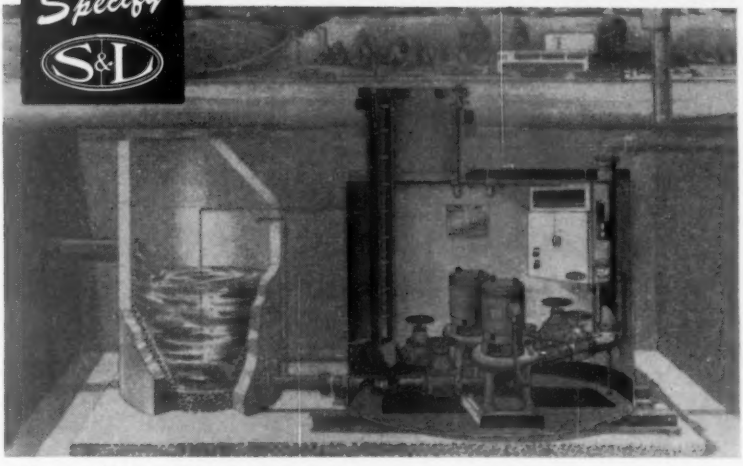
We will be pleased to quote on any type of water controlling equipment.

SNOW Gates & Valves

2437 East 24th Street **Los Angeles 54, Calif.**

Specify S&L

FACTORY-BUILT SEWAGE PUMP STATION

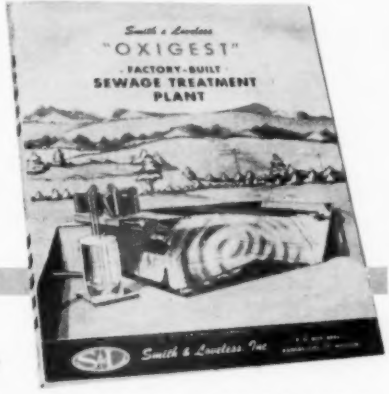


Over 1,000 installations from coast-to-coast, including Alaska and Canada prove the merit of specifying Smith & Loveless Factory-Built sewage pump stations . . . America's finest! The compact, easy-to-maintain Smith & Loveless pump station is economical, efficient and manufactured of the finest materials. It is easily and quickly installed following delivery to the job site on special Smith & Loveless trucks.

Smith & Loveless offers a complete line of lift stations with capacities from 20 GPM to 4800 GPM.

For job recommendations, complete specifications and drawings write today for our free, 100-page data manual on pump stations and pneumatic ejector lift stations. Write Department 30F

Write Today!



"OXIGEST"

FACTORY-BUILT TREATMENT PLANT FOR SMALL SUB-DIVISIONS

The Smith & Loveless "Oxigest" is a low-cost, factory-built sewage treatment plant for small sub-divisions, schools, motels and factories. It has been carefully engineered for dependable treatment without requiring a skilled operator. Built of the finest materials, the "Oxigest" will provide a permanent plant with minimum annual maintenance.

This complete factory-built unit is available in 27 standard sizes to cover a wide range of applications. It is easily and quickly installed after delivery to the job site on special Smith & Loveless trucks.

Write today for free data manual containing design notes, selection charts, dimension drawings and specifications. Write Department 300

S&L

Smith & Loveless, Inc.

P.O. BOX 8884 • KANSAS CITY 15, MISSOURI

Representatives in principal cities

AUTOMATIC LUBRICATION For Centrifugal Pump Glands

The Z-F Grease Seal applies constant positive lubrication to packing and shaft – automatically. Improved shut-off mechanism permits use of either grease or oil.

No more trouble spot where shaft enters casing – eliminates excessive heat, rapid wear, leakage and scoring.

Horizontal or vertical mounting. Many other advantages too. Write for complete description and price.

Zimmer & Francescon, P. O. Box 359, Moline, Ill.

ZF

MISSISSIPPI SEWAGE AND INDUSTRIAL WASTES ASSOCIATION

The 2nd Annual Meeting of the Mississippi Sewage and Industrial Wastes Association was held at the Robert E. Lee Hotel, Jackson, Miss., Mar. 6, 1959. The total registration was 123.

During the one-day meeting the following subjects were discussed:

"Water as an Industrial Asset," by Henry Maddox, Director, Mississippi Agricultural and Industrial Board, Jackson, Miss.

"Metropolitan Area Drainage," by Ralph E. Fuhrman, Executive Secretary, FSIWA, Washington, D. C.

(*Continued on page 400a*)

WEMCO® the INCREDIBLE Torque-Flow Pump

pumps almost everything

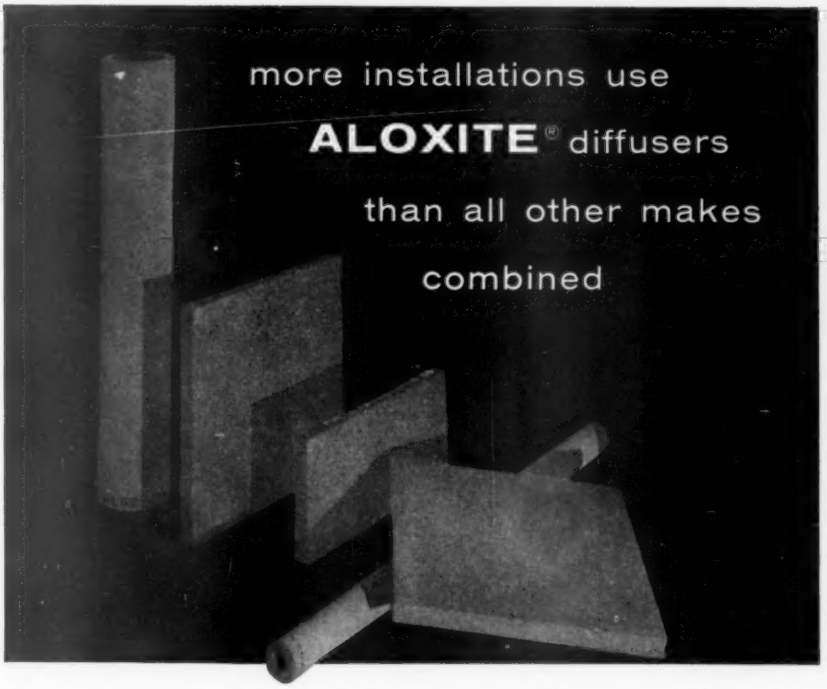
(what will go in will come out)

secret: recessed impeller; continuous open passage

(with downtime virtually eliminated)

Western Machinery Company 650 Fifth Street • San Francisco, Calif.

FIVE REASONS WHY



Since the discovery of the activated sludge process (in 1915) only one diffuser material has stood the test of time. Only porous ceramic diffusers have been used with continued success. And more installations have been made with ALOXITE® aluminum oxide diffusers than all other makes combined. Hundreds are in operation—many after over 20 years' service. Here are 5 reasons why:

1. A highly uniform grain structure in ALOXITE diffuser plates and tubes assures a uniform, small-bubble diffusion. That means optimum oxygen absorption.

2. ALOXITE diffusers have a relatively smooth surface. This fact, coupled with the glass-like ceramic bond that coats each grain, minimizes pressure loss and clogging.

3. ALOXITE diffusers never lose their corrosion resistance.

4. ALOXITE diffuser plates and tubes are adaptable to virtually every cleaning method.

5. ALOXITE diffusers have great strength and ruggedness for long life.

ALOXITE diffusers are available in plate or tube form, and in a full variety of grades. This permits maximum flexibility of design. It also lets you select the exact grade for a given function (consistent with air supply quality, pressure loss characteristics, and over-all life). This is particularly important since the introduction of the oxygen absorption test.

ANSWER ALL YOUR QUESTIONS about porous media with this up-to-date 56-page booklet.

CARBORUNDUM

Trade Mark

Write to: The Carborundum Company, Refractories Division, Perth Amboy, New Jersey.

HELP WANTED

SUPERINTENDENT OF SEWAGE

Graduate Civil or Sanitary Engineer. Prefer previous experience in operation of activated sludge plant. Salary to $8556 per year, plus fringe. **Address inquiries to:**

Personnel Department
Post Office Box 427
City of El Cajon
California

"The Control and Treatment of Poultry Processing Wastes," by A. J. Steffen, Director of Sanitary Engineering, Wilson and Company, Chicago, Ill.

"Factor Affecting the Design of Waste Stabilization Ponds in Southeastern States," by W. W. Towne, Robert A. Taft Sanitary Engineering Center, USPHS, Cincinnati, Ohio.

The address at the annual luncheon was made by J. O. Emmerich, Editor, Jackson, Miss., *State Times*.

At the business session the following officers were elected for the year 1959–60:

President: Howard K. Williford, State College.
Vice-President: James E. Jagger, Forest.
Secretary-Treasurer: Neil G. McMahon, Jackson.

NEIL G. MCMAHON
Secretary-Treasurer

UNUSUAL OPPORTUNITY

Expanding sales and research in our field of sewage and waste treatment and water purification has created openings in our staff for one senior and two junior sanitary engineers.

These technical executives will be stationed at our plant and general offices in Aurora, Illinois.

Write in complete confidence and in detail giving us all the information you feel we will require to lay the foundation for a personal interview.

Office of the President
The American Well Works
Aurora, Illinois

SALES ENGINEER

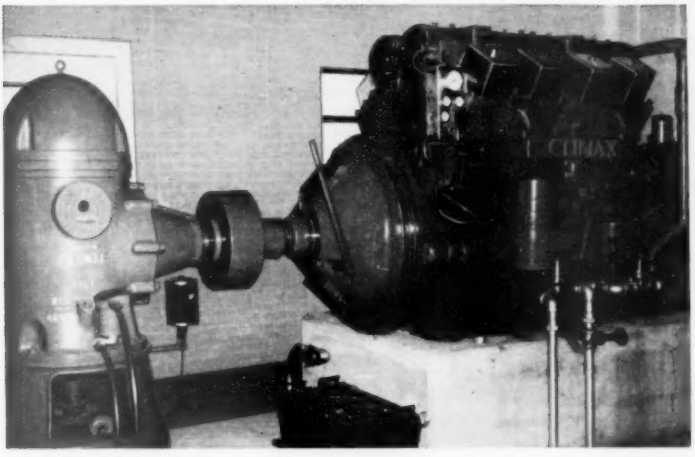
Excellent opportunity for capable and experienced Sales Engineer with long established machinery manufacturer. Man we need will have from five to ten years experience in treatment of sewage and industrial wastes—preferably with engineering degree. He must be personable and aggressive, with ability to work with operating engineers and executives. Headquarters: New England area. This is a top level opportunity requiring a seasoned sales engineer in a specialized field who can justify an attractive salary. All correspondence held confidential. Send resume to Box K, Sewage and Industrial Wastes, 4435 Wisconsin Avenue, N. W., Washington 16, D. C.

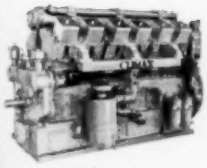
SEE US AT BOOTH 43

ANNUAL CONVENTION—DALLAS

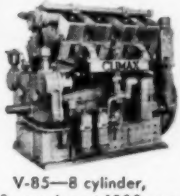
OCTOBER 11-15

CLIMAX MUNICIPAL ENGINES

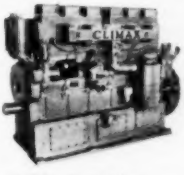




V-125—12 cylinder,
605 max. hp. at 1200 rpm.
V-122—12 cylinder,
520 max. hp. at 1200 rpm.



V-85—8 cylinder,
390 max. hp. at 1200 rpm.
V-80—8 cylinder,
340 max. hp. at 1200 rpm.



K-75—6 cylinder,
304 max. hp. at 1200 rpm.
K-67—6 cylinder,
265 max. hp. at 1200 rpm.

IN SEWAGE TREATMENT PLANTS everywhere Climax engines power sewage pumps, blowers and generators. Burning sludge gas, and utilizing heat from jacket water and engine exhaust gas to heat digesters and buildings, they effect big savings. Capable of operation on natural gas, butane, gasoline, or any combination. For continuous duty service in sewage plants—eight rugged Climax models: 12, 8, 6, 4 cylinders.

IN WATER WORKS over 100 cities depend on Climax engines... for prime power, or to take over when normal power for pumps is interrupted or fails... and to drive pumps during peak loads as supplementary power. Burning natural gas, butane or gasoline Climax Water Works engines range in size to 600 hp.

Write direct for bulletins, specifications and engineering consultation.

CL-100

BASIC MAX. ENGINE HP (Natural Gas and Gasoline) ①					600	700	800	900	1000	1100	1200
MODEL	No. of Cyls.	Bore & Stroke	Displ.	Torque @ RPM	BRAKE HORSEPOWER AT SPEEDS INDICATED						
R-110	4	6⅛ x 7	824	610 @ 800	68	83	94	105	115	123	125
R-165	6	6⅛ x 7	1238	930 @ 750	105	123	140	156	170	183	192
K-67	6	7 x 7	1616	1240 @ 805	140	165	188	210	230	248	265
K-75	6	7½ x 7	1855	1410 @ 800	160	186	214	240	265	286	304
V-80	8	7 x 7	2155	1610 @ 850	178	210	241	272	300	323	340
V-85	8	7½ x 7	2474	1860 @ 900	207	249	285	317	345	370	390
V-122	12	7 x 7	3232	2440 @ 900	280	330	380	420	460	490	520
V-125	12	7½ x 7	3711	2880 @ 850	310	370	435	490	540	580	605

① Basic engine includes ignition, maximum carburetion, and water pump. Ratings indicate maximum horsepower.

CLIMAX ENGINE MANUFACTURING CO. • FACTORY—CLINTON, IOWA
DIVISION OF WAUKESHA MOTOR COMPANY

HELP WANTED

SUPERINTENDENT OF SEWAGE

Graduate Civil or Sanitary Engineer. Prefer previous experience in operation of activated sludge plant. Salary to $8556 per year, plus fringe. **Address inquiries to:**

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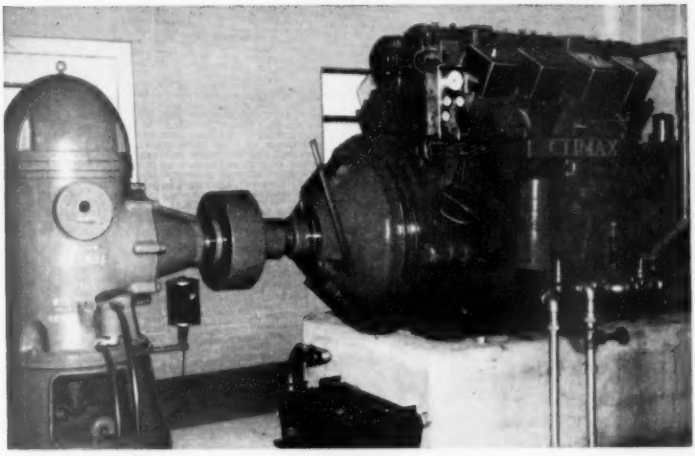

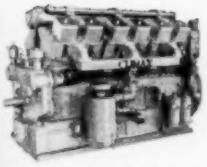

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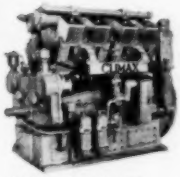

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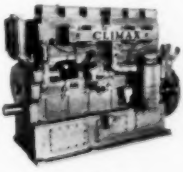

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CLIMAX ENGINE MANUFACTURING CO. • FACTORY—CLINTON, IOWA
DIVISION OF WAUKESHA MOTOR COMPANY

FSIWA PUBLICATIONS

MANUALS OF SEWAGE AND INDUSTRIAL WASTES PRACTICE

Manual Number	Title	Price to Members*	Price to Non-Members*
1	Safety in Wastewater Works	$0.75	$1.50
2	Utilization of Sewage Sludge as Fertilizer	0.75	1.25
3	Municipal Sewer Ordinances (Revised)	—†	—†
4	Chlorination of Sewage and Industrial Wastes	1.00	1.25
5	Air Diffusion in Sewage Works	1.00	1.25
6	Units of Expression for Wastes and Waste Treatment	0.25	0.50
7	Sewer Maintenance	—†	—†
	Multiple wire binder for above manuals	2.00	2.00
8	Sewage Treatment Plant Design	3.50	7.00
9	Design and Construction of Sanitary and Storm Sewers	3.50	7.00
	Uniform System of Accounts for Sewer Utilities (revised)	—†	—†

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INDEX, SEWAGE WORKS JOURNAL, Volumes 1–20, 1928–1948 (Subject, Author, and Geographic), buckram, $4.50.

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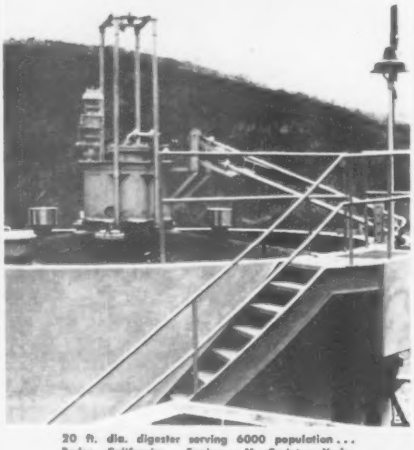

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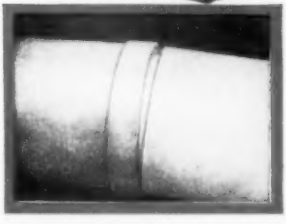
FOR YOUR MOST DEMANDING PROJECTS

...the premium pipe with the Flexible Joint!

LOCK JOINT ROLLER SUSPENSION PIPE with the FLEXIBLE JOINT RUBBER GASKET is the ideal answer to installations requiring highest quality sewer or culvert pipe and maximum protection against ground water infiltration.

This pipe, produced in diameters from 12" to 72" and in standard lengths of eight feet is manufactured by an unique process which develops unusually strong, dense concrete, highly resistant to abrasion. Its joint ends, of almost machined accuracy, are particularly adaptable to the Lock Joint Flexible Joint Rubber Gasket.

This gasket gives effective relief from infiltration into the pipeline and permits the joint to be opened up to ¾" without endangering its tightness. This feature alone adds considerably to the ease and speed with which the line can be installed.



The "Flexible Joint" gasket permits ample deflection to accommodate normal ground settlement.

Lock Joint also produces conventional machine made and cast concrete sewer and culvert pipe ranging from 6" to 120" and upward in diameter. All Lock Joint Pipe may be designed to comply with A.S.T.M., state highway or individual specifications.

LOCK JOINT PIPE CO.

East Orange, New Jersey

Sewer and Culvert Pipe Plants:

Kenilworth, New Jersey	Valley Park, Missouri	Cheyenne, Wyoming
Hartford, Connecticut	N. Kansas City, Missouri	Casper, Wyoming
New Haven, Connecticut	Tulsa, Oklahoma	Tucumcari, New Mexico
Beloit, Wisconsin	Oklahoma City, Oklahoma	Hato Rey, Puerto Rico
Chicago, Illinois	Wichita, Kansas	Ponce, Puerto Rico
Rock Island, Illinois	Denver, Colorado	Caracas, Venezuela

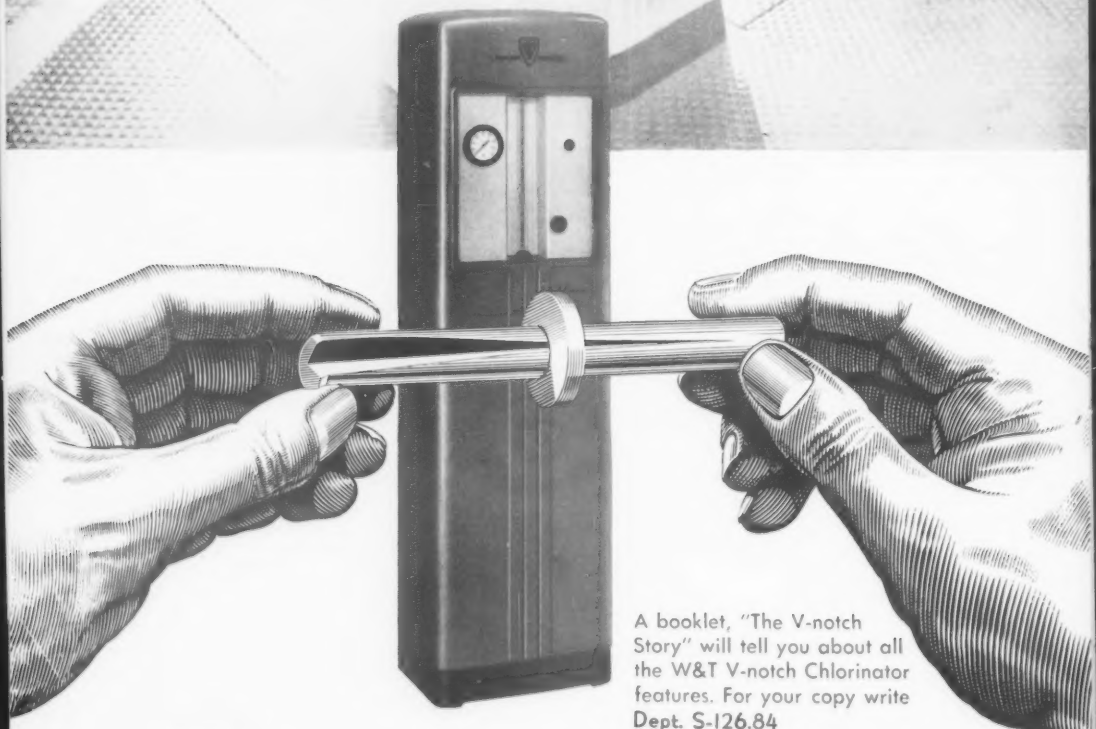
Also Great Lakes Concrete Pipe Company with plants at Buffalo, N. Y. and Henrietta, N. Y.

LANCASTER PRESS, INC., LANCASTER, PA.

the V-notch

is the difference in chlorine control

Safe chlorine control is the job of a chlorinator.
This control, the V-notch, does the job completely.
Yet it appears to be simply a grooved plug in a ring.
It is, of course, more than that... much more.
The groove in the plug is precision milled and shaped so that when you turn the control knob on your chlorinator and the plug slides through the ring, the size of the opening between the groove and the ring changes an exact amount. You meter chlorine exactly and simply because every position of the plug in the ring makes a repeatable orifice size—a repeatable chlorine flow rate.
Only in a W&T V-notch Chlorinator is control so simple, so true, so precisely right.
And, of course, the right plastics make the whole chlorinator chlorine-proof.



A booklet, "The V-notch Story" will tell you about all the W&T V-notch Chlorinator features. For your copy write Dept. S-126.84

WALLACE & TIERNAN INCORPORATED

25 MAIN STREET BELLEVILLE 9, NEW JERSEY